# TECHNOLOGY

QUARTERLY BULLETIN OF THE PLANNING & DEVELOPMENT DIVISION
FERTILIZER CORPORATION OF INDIA LTD.

Phone: Jharia 6541-44 (4 lines) SINDRI, BIHAR Gram: PLANDEV, Sindri

Vol. 5 JANUARY - MARCH 1968 No. 1

CFTRI

## CONTENTS

FACTORS AFFECTING DIFFUSION RATES IN WATER GAS SHIFT REACTION CATALYST
*by S. P. Sen and Bhaskar Sen* .. .. .. .. .. 3

GRAVIMETRIC ESTIMATION OF GUANIDINE BY HEXANITRO-DIPHENYLAMINE
*by Pasupati Ghosh and J. M. Sarkar* .. .. .. .. .. 7

CHARACTERIZATION OF THE HUMIC ACIDS OF SOME INDIAN SOILS
*by Subrata Dutta, Sisir Mukherjee and H. Roy* .. .. .. .. 10

CORROSION OF SILLIMANITE BY COAL ASH SLAG
*by S. K. Sharma, R. Chowdhury, Sisir Mukherjee and H. Roy* .. .. .. 13

PHYSICO-CHEMICAL AND MINERALOGICAL INVESTIGATION OF VARIOUS INDIAN SOILS
*by S. C. Chatterjee and B. K. Dhar* .. .. .. .. .. 20

A SERVO-TYPE MAGNETIC BALANCE FOR ROUTINE THERMOMAGNETIC ANALYSIS
*by P. C. Banerjie, S. N. Pandey, L. M. Mazumdar & P. K. Ghosh* .. .. 24

SHORT COMMUNICATIONS

Investigation into the Use of Algae for Removing Ammonium Nitrogen from Nitrogenous Industrial Wastes Part—2 Semi-Continuous Laboratory Studies
*by G. S. Bhattacharyya, G. S. Roy and B. K. Dutta* .. .. .. 31

Physical Studies on Coprecipitated Oxides Part 2: $Fe_2O_3$—$Cr_2O_3$ System
*by Sisir Mukherjee and H. Roy* .. .. .. .. .. 38

Corrosion in Water Scrubber in an Ammonia Plant
*by K. M. Verma, M. P. Gupta, S. C. Verma, H. Ghosh and A. K. Roy* .. 43

Studies on Corrosion Cracking of Stainless Steel Vessels of an Air Liquefaction Plant
*by Ajit Roy, C. V. Srinivasan, P. K. Ghosh and C. Aravindakshan* .. .. 45

Crystallographic Data for Dimethylene Triurea
*by C. Aravindakshan and B. K. Banerjee* .. .. .. .. 50

Examination of the Core Structure of Granular Calcium Ammonium Nitrate
*by M. Samaddar and H. Roy* .. .. .. .. .. 52

IN THE INDIAN CONTEXT

Phosphoric Acid by Wet Process with Special Reference to the Process Development by FCI Ltd.
*by R. Champati and B. B. Roy* .. .. .. .. .. 56

LETTER TO THE EDITOR .. .. .. .. .. .. 64

NOTES AND NEWS .. .. .. .. .. .. 66

NEWS IN BRIEF .. .. .. .. .. .. 74

STATISTICS .. .. .. .. .. .. 77

SPECIAL PAPERS

1. Appraisal of Scientific and Philosophical Concepts in Ancient India in the Light of the Theory of Universal Wave *by K. R. Chakravorty* S1
2. Thermodynamics and External Agency *by K. R. Chakravorty* S37

EDITOR: S. N. ROYE
TECHNICAL ASSISTANTS: BENOY K. BANERJEE & S. A. KULKARNI

The opinions expressed by the authors are their own and do not necessarily reflect the views of the Planning and Development Division of the Fertilizer Corporation of India Ltd.

## EDITOR'S NOTE

It has now been decided to publish in TECHNOLOGY research papers from scientists and technologists outside FCI Ltd., provided these are :

(i) original and related to fertilizers,

(ii) approved by external referees chosen by the Editor, and

(iii) communicated from reputed institutions, and written by workers with adequate experience.

Papers for publication in TECHNOLOGY are therefore welcome. These should be sent in duplicate (complete with illustrations and abstracts) to the Editor.

Any paper, article or short communication published in this bulletin can be reproduced with permission of the Editor. While news and other items do not require permission, their acknowledgement will be appreciated.

---

## TECHNOLOGY
## OFFER FOR EXCHANGE

This bulletin, TECHNOLOGY, is offered in exchange with other scientific and technical journals for mutual benefit. It is already being exchanged with more than fifty journals–foreign and Indian. Editors of journals devoted to fertilizer technology, applied chemistry, chemical engineering, food technology, agronomy, agricultural chemistry, soil science, fuel technology and other technologies may write to the Editor of TECHNOLOGY.

# Factors Affecting Diffusion Rates in Water Gas Shift Reaction Catalyst*

By

S. P. Sen and Bhaskar Sen,

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

The role of structural parameters under different operating variables on $Fe_2O_3$—$Cr_2O_3$ type water gas shift reaction catalysts has been discussed. Diffusion coefficient values for different pore ranges have been calculated and the extent and nature of diffusion restrictions have been ascertained. Pore volume, pore size distribution in the range 180 to 80,000 Å and surface area of three different commercial water gas shift reaction catalysts have been measured.

The results indicate that the catalyst having maximum surface area and greater aggregate of fine pores possesses high activity in the lower temperature region, whereas the increasing temperature causes lowering of activity to such an extent that in the region of 500°C its activity is almost equal to those having lesser surface area and bigger pores. It has also been observed that both increase in operating pressure and reduction in catalyst size lead to increase in activity. This has been explained on the basis of diffusion mechanism.

The role of structural parameters in evaluating catalytic reaction rates is widely known. Determinations of pore size distribution, pore volume, surface area, etc. are very helpful to probe into the mechanism and reaction rates of the catalytic processes. However, most of these data as they are obtained in laboratories by conventional methods cannot always explain the behaviour of a catalyst under industrial conditions. This appears to be primarily due to the fact that in commercial units the operating conditions like temperature, pressure and catalyst size are different from those adopted for laboratory measurements. From the point of view of development of industrial catalysts, it is desirable that the data be computed in such a way that the effects of these variables are accounted for.

This paper is concerned with determination of some structural parameters viz. pore size distribution, pore volume and surface area of commercial water gas shift reaction catalysts of $Fe_2O_3$-$Cr_2O_3$ type. The factors which govern transport of reactant molecules under reaction conditions constitute the main part of the investigation. The various aspects of suitable application of the physico-chemical data for evaluation of a catalyst under industrial conditions have also been discussed.

Three varieties of water gas shift reaction ($CO+H_2O \rightarrow CO_2+H_2$) catalyst of 10 mm. $\times$ 10 mm. size obtained from different manufacturers have been used in this investigation.

## Experimental

All the physico-chemical measurements were performed on the reduced samples. The pore size distributions were measured by mercury penetration method using an Aminco Winslow porosimeter having working pressure range up to 5,000 lbs/sq.in.

The total pore volumes were determined by mercury and helium displacement and the surface area by B.E.T. methods. The catalyst testing unit used for determining the activities was similar to that described earlier[1].

## Results

The pore size distribution and volume of pores in the range 180 to 80,000 Å pore radii, the total pore volumes and sufrace area of all the three catalysts are given in Table 1. The results indicate that catalyst

* Paper read at the Seminar on Chemisorption and Catalysis held in Madras, March 27-31, 1967

TABLE 1—Pore Size Distribution (180-80,000 Å)

| Radius, Å | Catalyst A | | Catalyst B | | Catalyst C | |
|---|---|---|---|---|---|---|
| | Pore Vol., c.c./g. | Vol., % | Pore Vol., c.c./g. | Vol., % | Pore Vol., c.c./g. | Vol., % |
| 180— 300 | .0610 | 76 | .0057 | 32 | .0216 | 9 |
| 300— 400 | .0048 | 6 | .0057 | 32 | .0288 | 12 |
| 400— 500 | .0032 | 4 | .0039 | 22 | .0288 | 12 |
| 500— 800 | .0048 | 6 | .0010 | 6 | .0480 | 20 |
| 800— 1,450 | .0032 | 4 | .0005 | 3 | .0523 | 22 |
| 1,450—80,000 | .0032 | 4 | .0009 | 6 | .0600 | 25 |
| Pore vol. between 180—80,000 Å c.c./g. | .0805 | | 0.178 | | 0.24 | |
| Total pore vol., c.c./g. | 0.288 | | 0.234 | | 0.27 | |
| Sp. surface area sq.m./g. | 20.80 | | 13.0 | | 7.5 | |

TABLE 2—Conversion Efficiency of Catalysts

| % CO Inlet | Space Velocity | Steam/ Gas Ratio | Pressure, atm. | Reaction Temp., °C | %CO in Converted Gas | | |
|---|---|---|---|---|---|---|---|
| | | | | | A | B | C |
| 30 | 1000 | 1.0 | 12 | 390 | 2.8 | 3.4 | 4.2 |
| 30 | 1000 | 1.0 | 12 | 450 | 3.4 | 3.8 | 4.7 |
| 30 | 1000 | 1.0 | 12 | 500 | 3.8 | 4.0 | 5.0 |

sample A is having maximum surface area and major distribution of fine pores. However, the total pore volumes obtained by mercury and helium displacement method for all the three catalysts are of the same order. In Table 2 the conversion efficiencies of all the three catalysts at temperatures 390, 450 and 500°C respectively are shown.

The effect of pressure has been investigated with catalyst A at 450°C with varying space velocities in the range of 450 to 1500 (Fig.1). This figure also includes the conversion curves obtained with reduced sizes of this catalyst at atmospheric pressure. The values of diffusion coefficient, parameter "h" and effectiveness factor E have been calculated in the pore range 85 to 1450 Å for two temperatures, viz. 360 and 450°C, respectively (Table 3). The change in the activity and the effectiveness factor for different sizes of catalyst B, at 375°C and steam to gas ratio of 1.5

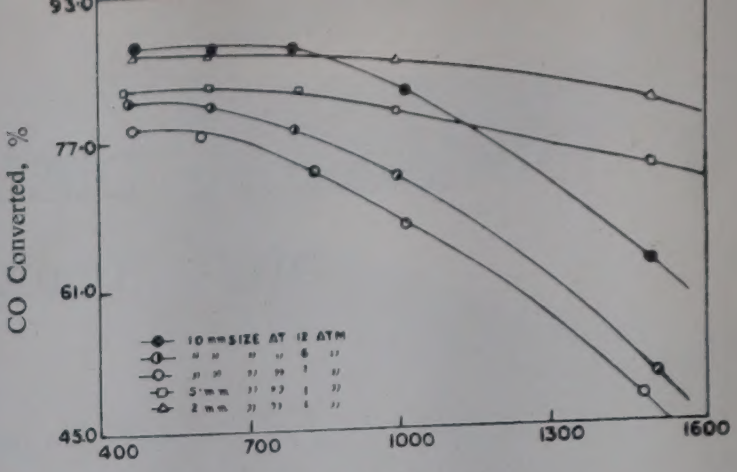


Fig. 1

are shown in Table 4. The essential features on the basis of which a quantitative assessment of diffusion characteristics is possible is briefly outlined below.

Industrial catalysts comprise a network of interconnecting pores and the major portion of the surface area is accounted for by the internal surface of these pores. In case of a catalyst having fine pores, the internal surface may not be readily available to the reactants due to restrictions offered by such pores. The surface rate processes with such a catalyst will increase rapidly with increase in temperature whereas

TABLE 3—Dependence of Diffusion Coefficient Deff Parameter h and Effectiveness Factor E on Pore Size and Temperature

| r (Å) | At 360°C and 12 atm. | | | At 450°C and 12 atm. | | |
|---|---|---|---|---|---|---|
| | $D \times 10^2$ | h | E | $D \times 10^2$ | h | E |
| 85 | 3.215 | 3.61 | 0.30 | 3.15 | 16.81 | 0.0595 |
| 100 | 3.81 | 3.11 | 0.34 | 4.25 | 13.35 | 0.075 |
| 150 | 5.21 | 2.19 | 0.40 | 5.95 | 9.13 | 0.1095 |
| 200 | 6.37 | 1.7 | 0.45 | 7.45 | 7.12 | 0.1045 |
| 250 | 7.29 | 1.42 | 0.50 | 8.55 | 5.94 | 0.1682 |
| 300 | 0.08 | 1.23 | 0.53 | 9.45 | 5.16 | 0.194 |
| 350 | 8.71 | 1.1 | 0.58 | 10.25 | 4.58 | 0.218 |
| 400 | 9.25 | 0.998 | 0.61 | 10.90 | 4.17 | 0.24 |
| 450 | 9.66 | 0.921 | 0.63 | 11.50 | 3.82 | 0.262 |
| 550 | 10.3 | 0.805 | 0.67 | 12.45 | 3.3 | 0.2935 |
| 650 | 10.73 | 0.725 | 0.70 | 13.2 | 2.884 | 0.347 |
| 750 | 11.01 | 0.668 | 0.73 | 13.65 | 2.72 | 0.368 |
| 850 | 11.21 | 0.621 | 0.75 | 13.9 | 2.528 | 0.395 |
| 950 | 11.33 | 0.585 | 0.78 | 14.05 | 2.363 | 0.424 |
| 1050 | 11.43 | 0.55 | 0.80 | 14.25 | 2.25 | 0.445 |
| 1150 | 11.5 | 0.527 | 0.84 | 14.27 | 2.122 | 0.471 |
| 1250 | 11.53 | 0.505 | 0.90 | 14.35 | 2.052 | 0.497 |
| 1450 | 11.67 | 0.458 | 0.98 | 14.44 | 1.84 | 0.552 |

TABLE 4—EFFECT OF CATALYST SIZE ON ACTIVITY AND EFFECTIVENESS FACTORS FOR CATALYST B AT 375°C AND STEAM-TO-GAS RATIO OF 1.5

| Size range, mm. | Activity | E |
|---|---|---|
| (a) 0.9—1.3 | $3.41\times10^{-3}$ | 0.975 |
| (b) 2.0—2.2 | $2.69\times10^{-3}$ | 0.942 |
| (c) 4.8—5.3 | $2.06\times10^{-3}$ | 0.720 |
| (d) 6.7—7.2 | $1.84\times10^{-3}$ | 0.643 |
| (e) 10×10 | $1.14\times10^{-3}$ | 0.40 |

*The activity with 0.4—0.52 mm. size was found to be equal to $3.5\times10^{-3}$ for which the effectiveness factor was taken to be equal to unity.

there will be only a negligible increase in the diffusion rates. The resultant effect of temperature is likely to increase the diffusion restriction.

An increase in catalyst size also prevents reactant molecules to freely avail of the internal sufrace. Thus, the factors which contribute to the retarding effects, commonly known as diffusion restriction, are: (a) fine pores (b) large catalyst size and (c) high temperature.

Depending on diameter of pores, two types of diffusion may operate. If the pore diameter is large compared to mean free path, diffusion of reactant molecules through the pores proceed according to a mechanism similar to that in bulk gas phase. This is termed as 'Bulk diffusion'. On the other hand, when the pore diameters are smaller than the mean free path, the molecules will collide with the pore walls more frequently than with other reacting molecules; this mechanism is known as "Knudsen diffusion". On the basis of kinetic theory the diffusion coefficients may be represented as

$$D_B = 1/3\ v\lambda \quad .. \quad (1)$$

$$D_K = 2/3\ vr \quad .. \quad (2)$$

The effective diffusion coefficient according to Wheeler[2] may be expressed as

$$D_{eff} = D_B\,(1-e^{-D_K/D_B}) \quad .. \quad (3)$$

Assuming the value of $\lambda = \frac{10^{-5}}{p}$, v = $10^5$cm/sec. and solving equations (1) and (2), the following expression can be worked out.

$$D = 1/3\ p\ (1-e^{-2.10^5.r.p}) \quad .. \quad (4)$$

The above expression (equation 4) reflects the nature of dependence of diffusion coefficient values on pore radii and pressure. A plot showing the values of D against pore radii at different pressures, according to Wheeler[3], is given in Fig. 2.

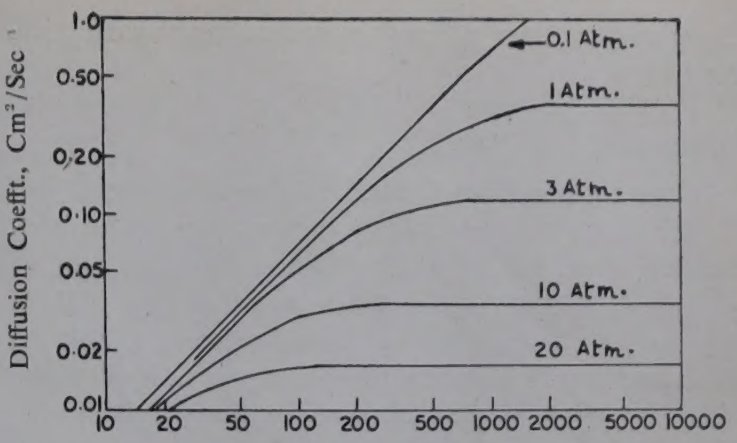



Fig. 2—Dependence of Diffusion Coefficient on Pore Radius at Difference Pressure.

As regards fraction of the internal surface available for reaction, it can be shown by following the treatment of Thiele and Wheeler- that

$$h = L\sqrt{\frac{2k}{rD_{eff}}}, \quad \ldots \quad (5)$$

where h is related to the fraction of surface available or the effectiveness factor by

$$\frac{\tanh h}{h} = E \quad (6)$$

It can be seen from equation (6) that the availability of internal surface decreases with increase in the value of h and vice versa. Fig. 3 presents a plot of h against

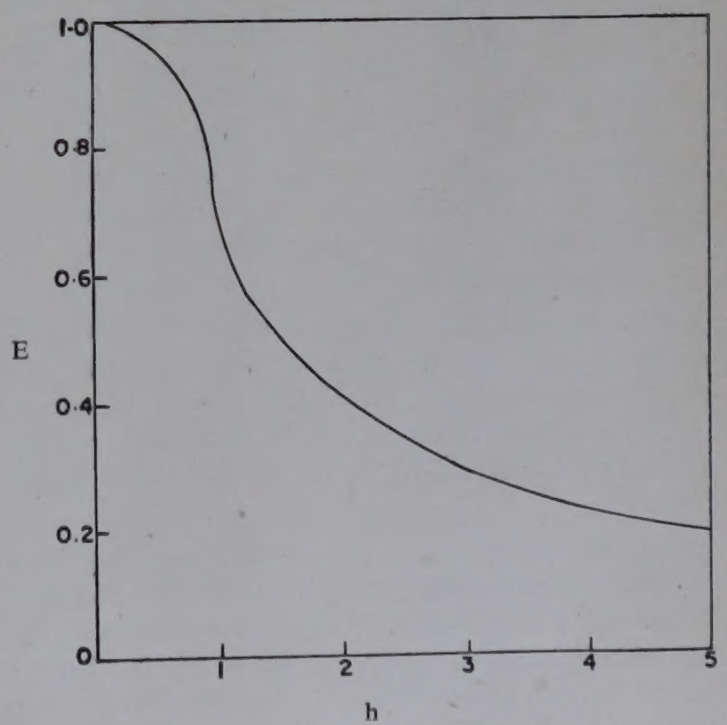



Fig. 3—Dependence of E on parameter h.

E which has been utilized in evaluating the effectiveness factors.

**Discussion**

It can be seen from Table 1 that compared to B and C, the catalyst A has higher surface area comprising smaller pores. On the basis of these data, the catalyst A should be more active than the other two. This is true only at lower temperatures of reaction (Table 2). With increase in temperature, the conversion efficiency of this catalyst is almost equal to that of B having lower surface area and comparatively larger pores. That this is not due to deterioration of the catalyst has been verified by checking the conversion efficiency of catalyst A at 390°C. It therefore follows that with increase in temperature some restrictions are offered to the reactants in availing of the internal surface through fine pores.

The value of h according to equation (5) will increase with increase of temperature. Again, increase in value of h corresponds to lowering of effectiveness factor.

The dependence of diffusion coefficient, parameter h and the effectiveness factor on both temperature and pore size has been shown in Table 3. The values of bulk diffusion coefficient have been calculated following the treatment. of Gililand[4], and that for Kundsen's, $D_K = 9.7 \times 10^3 \times R\sqrt{\frac{T}{M}}$ was used. The effective diffusion coefficient $D_{eff}$ was then calculated from equation (3). From this table it can be seen that for any pore size, the effectiveness factor decreases with increase of temperature under identical conditions of space velocity, steam/gas ratio and operating pressure, the rate of fall being more in case of lower size pores. This explains the observed fact that with increase in temperature the activity of a catalyst having finer pores in spite of higher surface area may fall and correspond to that having lower surface area.

The curves (Fig. 1) reveal that increase of pressure tends to increase the conversion efficiency. As the reaction concerned is not associated with any volume change, this increase in conversion can only be attributed to greater availability of internal surface at higher pressure[1,5].

It can be seen from Fig. 2 that with increasing pressure the Knudsen's diffusion gets transformed to bulk diffusion. The curves (Fig. 2) show that at higher pressure bulk diffusion is operative even in the small pores region. Conversely, at lower pressure Knudsen diffusion is predominant and operate over a wide range of pores. The observed effect of pressure on conversion efficiency may be explained on this basis.

The data (Table 3 and Fig. 2) also indicate that for correct evaluation of effect of the variables like pressure and temperature on diffusion coefficient, effectiveness factor, etc., it is desirable to take into consideration the pore size distribution, instead of taking the value of average pore radius.

Similar to the effect of pressure, reduction in size also increases the activity of water gas shift reaction catalyst. This is presumably due to the exposure of more of the internal surface to the reactant molecules. An idea of the extent of availability of internal surface with size reduction can be obtained from Table 4.

From Fig. 1 it can be seen that both 2 and 5 mm. sized catalysts show conversion higher than that of the 10 mm. size at 6 times higher pressure. Further, the activity of 2 mm size catalyst corresponds to what can be obtained with 10 mm size by working at 12 times more pressure. At higher space velocity region, the curves with lower sizes differ from those obtained with bigger size at higher operating pressure. With lower size, the rate of fall in conversion with increasing space velocity is always less than the 10 mm size operating at increased pressures. This may be attributed to the fact that pressure alone cannot completely overcome the diffusion restriction offered due to structural characteristics inherent with the bigger size catalyst. On the other hand, by reduction in size it is possible to approach to a stage where the whole of the internal surface may be available for reaction.

**Nomenclature**

$D_B$ = Bulk diffusion coefficient, cm².sec.
$D_K$ = Knudsen diffusion coefficient, cm².sec.
$D_{eff}$ = Effective diffusion coefficient, cm².sec.
$\lambda$ = Mean free path, cm.
v = Average moleculer velocity, cm./sec.
r = pore radius, Å
p = Pressure, atm.
h = a dimensionless parameter which determines the fraction of internal surface available or the effectiveness factor.
E = Effectiveness factor.
L = Average pore length, cm.
k = Reaction rate con stant, cm./sec.
T = Temperature,°K
M = Molecular weight.

REFERENCES

1. Sen, S. P., Aggarwal, S. C. and Chakravorty, K. R., *Indian J. Appl. Chem.*. **29** (1966), 191.
2. Wheeler, A., *Catalysis*, Vol. II (Reinhold Publishing Corpr., New York), 1955, 128.
3. Wheeler. A., *Advances in Catalysis*, Vol. 3 (Academic Press Inc. New York), 1951, 282.
4. Gilliland, E. R., *Indus. Eng. Chem.*, **26** (1934), 681.
5. Atwood, K., Arnold, M. R. and Appel, E. G., *Indus. Engng. Chem.*, **42** (1950), 1600.

# Gravimetric Estimation of Guanidine by Hexanitro-Diphenylamine

By

PASUPATI GHOSH AND J. M. SARKAR

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

A new method for gravimetric estimation of guanidine to 99.9 per cent accuracy by dipicrylamine has been developed. As low as 0.5 per cent concentration of guanidine can be estimated with fairly good accuracy by this method. A conventional method for estimating guanidine in presence of appreciable amount of contaminants like ammonium nitrate by calcium picrate gives higher results. But with some modifications, this newly developed method can estimate guanidine in presence of common contaminants like ammonium nitrate, urea, dicyandiamide and melamine.

## Introduction

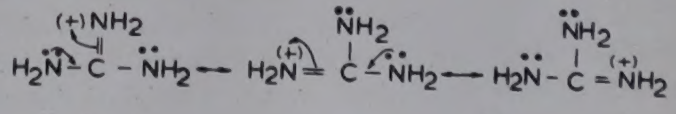
Generally guanidine is estimated gravimetrically as its picrate, Vozarik[1] had employed ammonium picrate as the precipitating agent and for a long time his method with slight modification[2,3] was the only one followed for guanidine estimation. The method was subsequently modified by Fainer and Myers[4] who showed that calcium picrate was more suitable reagent than ammonium picrate as the former gave better results and its use like ammonium picrate was not critically dependent on the conditions of the experiment. Among other advantages of their method mention may be made of its successful application for the estimation of guanidine in the presence of small amount of impurities, like ammonium nitrate and urea. But in the presence of appreciable amount of ammonium nitrate this method when tried by authors was found to give higher results, due to the formation of ammonium picrate.

Kertes and Kertes[5] found that hexanitro-diphenylamine react with organic bases like alkyl-amines, pyridine, piperidine etc., and studied the possibility of methods for the colorimetric estimation of these weak organic bases. Quantitative estimation of strong inorganic bases like potassium, rubidium and caesium by hexanitro-diphenyl-amine is now well established[6]. These studies led the authors to carry out experiments and develop a method for quantitative estimation of guanidine by hexanitro-diphenylamine.

## Theory

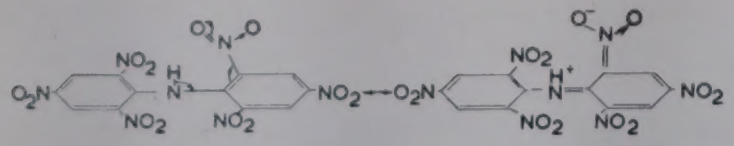
The reaction between guanidine and hexanitro-diphenylamine is an acid base reaction, the former being the base and the latter being acid.

The basicity of guanidinium ion is ascribed to the following resonating forms:

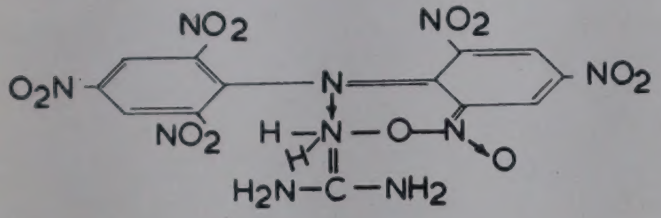


The acidic nature of hexanitro-diphenylamine is attributed to the H of –NH, the lability of H is due to the electron withdrawing effect by six nitro groups in the

two benzene nucleus. Two of the resonating forms are given below:



From the above it is apparent that a compound formation is possible by the reaction between guanidine and hexanitro-diphenylamine. The probable structure of which on the analogy of that of the potassium dipicrylaminate was postulated to be as under:



Preliminary infrared spectrum analysis carried out supports the above structure.

## Materials

*Magnesium-dipicrylaminate Reagent:* In 400 ml. of distilled water 1.5g. of magnesium oxide (E.Merck) was thoroughly dispersed and 12 g. of dipicrylamine (Hexanitro-diphenyl-amine) was gradually added. The mixture was kept under constant stirring for 12 hours and allowed to stand overnight, and then filtered through Whatman No.42 filter paper. The strength of the solution was found to be 2.5 per cent in terms of dipicrylamine (H.D.P.A.) which was used in the experiment.

Guanidine nitrate used was of reagent grade, (B.D.H. product) which had been recrystallised twice from water at 55°C and finally from alcohol and dried.

## Experimental

For estimation, solution was prepared by adding 20 ml. of distilled water to a weighed amount of guanidine nitrate. Measured volume of magnesium-dipicrylaminate solution was added to this freshly prepared guanidine nitrate solution and guanidine-dipicrylaminate precipitated out. The precipitate formed was allowed to stand for two hours. Then after cooling in an ice bath for half an hour was filtered through a weighed sintered $G_4$ glass crucible under suction. The precipitate was washed first with a saturated guanidine dipicryl-aminate solution and then with three 5 ml. portions of ice cold water and dried at 110°C to constant weight.

Estimation of guanidine in presence of ammonium salt and other contaminants was carried out by initially converting the ammonium salt with formaldehyde to hexamethylene-tetramine and neutralizing the liberated acid with dilute sodium hydroxide following the procedure laid down by Kolthoff and Stenger[7] and then proceeding as above. All the determinations were carried out at the pH of the reagent i.e. round 8.

TABLE 1

| No. of Experiments | Guanidine Nitrate taken, g. | Strength of Solution, % | Wt. of the guanidine dipicrylamine precipitate, g. | Wt. of guanidine nitrate found, g. | Precentage of precipitation |
|---|---|---|---|---|---|
| 1. | 0.6000 | 3.00 | 2.4480 | 0.5997 | 99.95 |
| 2. | 0.5520 | 2.76 | 2.2518 | 0.5517 | 99.95 |
| 3. | 0.5090 | 2.54 | 2.0767 | 0.5088 | 99.96 |
| 4. | 0.4682 | 2.34 | 1.9102 | 0.4680 | 99.95 |
| 5. | 0.4320 | 2.16 | 1.7642 | 0.4318 | 99.95 |
| 6. | 0.4040 | 2.02 | 1.6485 | 0.4038 | 99.95 |
| 7. | 0.4032 | 2.01 | 1.5450 | 0.4030 | 99.95 |
| 8. | 0.3625 | 1.81 | 1.4789 | 0.3623 | 99.95 |
| 9. | 0.3463 | 1.73 | 1.4128 | 0.3461 | 99.94 |
| 10. | 0.3117 | 1.56 | 1.2714 | 0.3114 | 99.90 |
| 11. | 0.2850 | 1.42 | 1.1624 | 0.2847 | 99.90 |
| 12. | 0.2510 | 1.25 | 1.0236 | 0.2507 | 99.92 |
| 13. | 0.2235 | 1.12 | 0.9110 | 0.2231 | 99.86 |
| 14. | 0.2168 | 1.08 | 0.8831 | 0.2163 | 99.77 |
| 15. | 0.1840 | 0.92 | 0.7493 | 0.1836 | 99.80 |
| 16. | 0.1575 | 0.78 | 0.6403 | 0.1568 | 99.55 |
| 17. | 0.1365 | 0.68 | 0.5504 | 0.1348 | 98.80 |
| 18. | 0.1043 | 0.52 | 0.4200 | 0.1029 | 98.60 |
| 19. | 0.0875 | 0.43 | 0.3505 | 0.0858 | 98.10 |

TABLE 2—EXPERIMENTAL RESULTS

| Guanidine Nitrate taken, g. | Ammonium Nitrate added, g. | Urea added, g. | Wt. of the guanidine dipicrylaminate | Wt. of the guanidine nitrate found, g. | Percentage of precipitation |
|---|---|---|---|---|---|
| 0.4000 | 0.1250 | — | 1.6231 | 0.3976 | 99.40 |
| 0.4000 | 0.2165 | — | 1.6228 | 0.3975 | 99.40 |
| 0.4000 | 0.3050 | — | 1.6233 | 0.3977 | 99.43 |
| 0.4000 | 0.4025 | — | 1.6244 | 0.3979 | 99.50 |
| 0.4000 | 0.5100 | — | 1.6242 | 0.3978 | 99.50 |
| 0.4000 | — | 0.1120 | 1.6232 | 0.3977 | 99.43 |
| 0.4000 | — | 0.2075 | 1.6236 | 0.3978 | 99.45 |
| 0.4000 | — | 0.3125 | 1.6236 | 0.3978 | 99.45 |
| 0.4000 | — | 0.4080 | 1.6243 | 0.3979 | 99.50 |
| 0.4000 | 0.1250 | 0.2075 | 1.6233 | 0.3977 | 99.43 |
| 0.4000 | 0.2165 | 0.2075 | 1.6236 | 0.3978 | 99.45 |
| 0.4000 | 0.3050 | 0.3125 | 1.6237 | 0.3978 | 99.45 |
| 0.4000 | 0.3050 | 0.4080 | 1.6243 | 0.3978 | 99.50 |

## Discussion

The factor for guanidine-dipicrylaminate to be converted into the weight of guanidine nitrate is 0.2450 (0.24498) calculated stoichiometrically. Experiments carried out to determine minimum amount of magnesium dipicrylaminate of 2.5 per cent strength required to obtain optimum yield of guanidine dipicrylaminate from a solution of guanidine nitrate showed that the magnesium-dipicrylaminate solution should be 20 per cent in excess of what is stoichiometrically required. Yield obtained under such condition was within 99.90 per cent of the theoretical value.

At lower concentration, accuracy goes down to 98.6 per cent or still lower. At a concentration of 1-2 per cent an accuracy of 99.96 per cent was obtained. At higher concentration uniformly good results were obtained. But as guanidine dipicrylaminate has a high molecular weight and the precipitate is quite voluminous, estimation with concentration higher than 4 per cent was not attempted. It was observed that for estimation of guanidine from its salt solution, the concentration of the salt solution should better be kept within the limit of 1-3 per cent.

When reactions were carried out at higher temperatures and the settling time given was 2-3 hours low results were obtained. It was, however, observed that crystals separated out on cooling were of larger and uniform size. Low result was obtained possibly because a part of guanidine dipicrylaminate which had gone into solution at higher temperature did not separate out during the settling time. Yield obtained had been uniformly good when the reaction was carried out at room temperature (i.e 25°C) with the settling time two hours and the precipitate was ice cooled before filtration.

From Table 2 it is evident that guanidine nitrate can be readily estimated in presence of contaminants like ammonium salts and urea and the accuracy was within 99.4-99.5 per cent of the theoretical value. A little lower result obtained was probably due to the solubility of guanidine-dipicrylaminate in the increased volume of water added as urea and ammonium nitrate solution and as caustic soda solution for neutralization. Reaction of urea with excess formaldehyde left in the system if any did not affect the determinations made. It was, however, observed that in such condition crystals of guanidine dipicrylaminate formed were smaller and fine. If the amount of ammonium nitrate is too high in the mixture it is recommended that the acid liberated should be neutralised initially with concentrated alkali nearer to the end point and then with dilute alkali so that the pH of the solution does not go above 8. Hexanitro-diphenylamine does not form any precipitate with urea, hexamethylene-tetramine, melamine, ammeline, ammelide and dicyandiamide. Experiments carried out to determine guanidine in presence of these contaminants usually present in a product obtained from a reaction of urea and ammonium nitrate in presence of silica gel gave satisfactory results.

## Conclusion

By this newly developed method guanidine can be estimated in presence of appreciable amount of ammonium nitrate; therefore, it can very well replace the method of estimating guanidine by calcium picrate method.


## Acknowledgement

The authors' thanks are due to Dr. K. R. Chakravorty, General Manager, Planning and Development Division, for his keen interest in the work. Our thanks are also due to Sri S. Ranganathan, Assistant Technologist, for his kind assistance.


## REFERENCES


1. Vozarik. Z., *Angew Chem.*, **15** (1902), 670.
2. Smith, Sabetta and Steinback, *Indus. Engng. Chem.*, **23** (1931), 1124.
3. American Cyanamide Co. "Cyanamide's Nitrogen Chemicals Digest". The Chemistry of Guanidine." Vol. IV. p. 37, (1950).
4. Fainer and Myers, *Anal. Chem.*, **24** (1952) 515.
5. Kertes and Kertes, *Anal. Chem. Acta*, **15**(1956), 73. in English.
6. Welcher, *Organic Analytical Reagents*, Vol. IV. p. 8-17, 1955.
7. Kolthoff and Stenger, *Volumetric Analysis*, Vol. II, p. 158, 1947

# Characterization of the Humic Acids of Some Indian Soils

By

SUBRATA DUTTA, SISIR MUKHERJEE AND H. ROY,

*Planning & Development Division*

*Fertilizer Corporation of India Ltd., Sindri, Bihar*

Humic acids extracted from three Indian soils and a ceramic clay were investigated in terms of their structural characteristics, equivalent weight and shape of the molecules. It was observed that their chemical structures are essentially of the same type but differ in some minor details, such as equivalent weight, the number of free acid groups, aggregation of the molecules and possibly arrangement of different units in their chemical structures.

Humic acids are the predominant constituents of soil organic matter. They represent usually a group of closely related substances being primarily in non-nitrogenous form although in many cases nitrogen is present in their molecules, coming, it is believed, from proteins combining with quinones in the main molecules[1]. The free radical content of humic acids is quite high (above 10 molar per cent)[2] and as such they form easily additive complex with many of the nitrogenous compounds, such as urea, $HCONH_2$ and $ACNH_2$[3], which are useful as slow-acting fertilizers. Again, many of the soil properties, such as its aggregate structure, water-holding and sorption capacities, etc., are largely determined by the nature and character of the humic acids. Attempts have been made to characterize humic acids from different origins by such physical methods as differential thermal anlaysis and electron microscopy[4,5]. DTA diagrams of humic acid samples collected from various sources have been found to be similar to each other, which indicates that their chemical structures are essentially of the same type[4]. Electron microscopic study[5] of humic acids reveals that they are amorphous in nature and consist of spherical aggregates of colloidal dimensions. Their equivalents as well as molecular weights vary over a wide range. These variations were reported to be within the ranges of 111-345 and 1000-59000 respectively[6]. Again, the extent of aromatization as well as the arrangement of different groups in their structures varies with the soil type[7].

An attempt has been made in the present investigation to study the humic acids extracted from three Indian soils and a ceramic clay with particular reference to the structural and other characteristics of the humic acids, which determine important soil properties.

**Experimental**

The Indian soils are: (1) Black cotton soil (from Maharashtra), (2) Ludhiana soil (from Punjab), (3) Chinsura soil (from W. Bengal), (4) the ceramic clay is a deposit in a coal bed from U.K. commercially known as Ball clay. The predominant clay minerals are: montmorillonite in sample 1, illite in sample 2, mixture of illite and montmorillonite in sample 3 and kaolinite in sample 4.

*Preparation of Humic Acids:* The samples were first sieved through 80 mesh to remove roots and coarse particles. About 200 g. of each sieved sample was treated with 500 c.c. of 2 per cent solution of sodium carbonate. The suspension was stirred for some time and heated to about 60°C on a hot plate for 1-2 hours. The suspension was then allowed to settle and the brown supernatant liquid was siphoned off. The process was repeated 5 to 6 times till the supernatant liquid turned faint brown. Each of the collected extracts was allowed to settle overnight and the supernatant liquid was siphoned off and acidified with hydrochloric acid to a pH about 2.5, when crude humic acids coagulated.

The residue after removing the supernatant liquid was dispersed using 2 per cent sodium carbonate solution and again coagulated. The process was repeated three times. The final material was then electrodialyzed. But the ash content of sample 1 was 7.2 per cent and that of the rest varied from 2.2-3.8 per cent. A preliminary x-ray examination of these samples also revealed that sample 1 was contaminated with clay minerals, whereas samples 2 and 3 contained other inorganic impurities. In order to remove them, the electrodialyzed suspension was dispersed with caustic soda solution (pH 10) and centrifuged for 2 hours at 5000 r.p.m. The supernatant liquid was siphoned off and passed several times through a column packed with H-form of Amberlite IR-120 resin. This procedure reduced the ash content of sample 1 to 2 per cent and of the rest below one per cent. In case of sample 1 the process was repeated but its ash content was not reduced further. X-ray analysis of the samples so purified could not detect presence of foreign constituents.

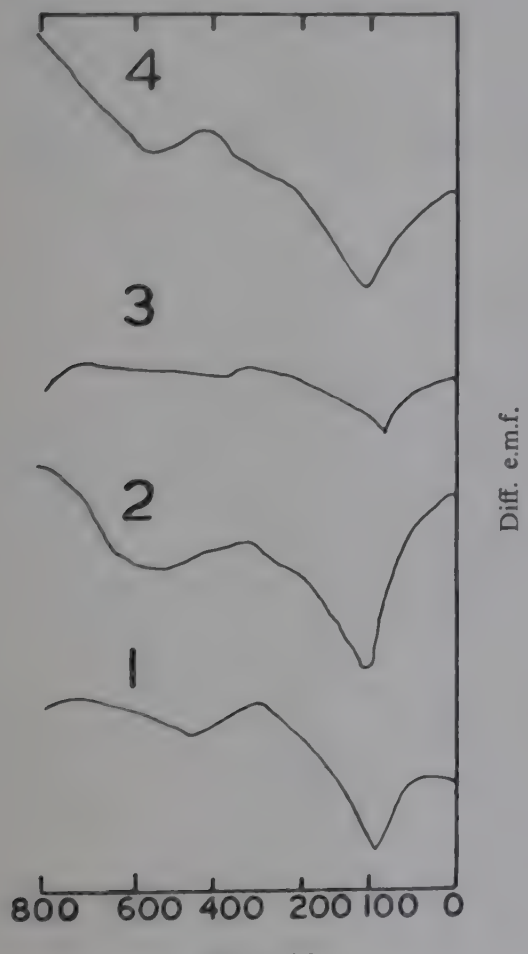



Fig. 1—DTA Thermograms of the Humic Acid Samples. 1, 2 and 3 represent samples from Black Cotton, Chinsura, Ludhiana Soils respectively; No. 4 is a Ball clay sample.

*Differential Thermal Analysis:* The Linseis model of DTA apparatus was employed using Pt and Pt/Rh thermocouple and nickel block sample holders were used. The rate of heating was about 10°C/min which was controlled by a programme controller. Oven-dried sample (60°C) was used with ignited alumina as reference substance. A nitrogen gas atmosphere was maintained inside the furnace by a suitable gas attachment during the experiment. DTA curves of the samples are shown in Fig.1 and the peak temperatures are given in Table 1.

TABLE 1—Temperature and Nature of the Peaks in the Thermograms of Humic Acids

| Sl. No. | Sample | Temperature (°C) and Nature of Peaks | | | |
|---|---|---|---|---|---|
| | | Endothermic | | Exothermic | |
| 1. | Black Cotton | 100 | strong | 290 | medium |
| 2. | Chinsura | 110 | ,, | 360 | ,, |
| 3. | Ludhiana | 90 | ,, | 330 | ,, |
| 4. | Ball Clay | 110 | ,, | 400 | ,, |

*Electron Microscopic Study:* A drop of humic acid suspension dispersed with caustic soda and suitably diluted was taken over a collodion covered grid and dried in air. The grid was then shadow-cast with platinum at 30°. The electron microscope* photographs were taken at 60 KV with the total magnification ranging from 1,05,000 to 2,28,000. The average sizes of the aggregates obtained from the microphotographs (Fig.2) are given in Table 2.

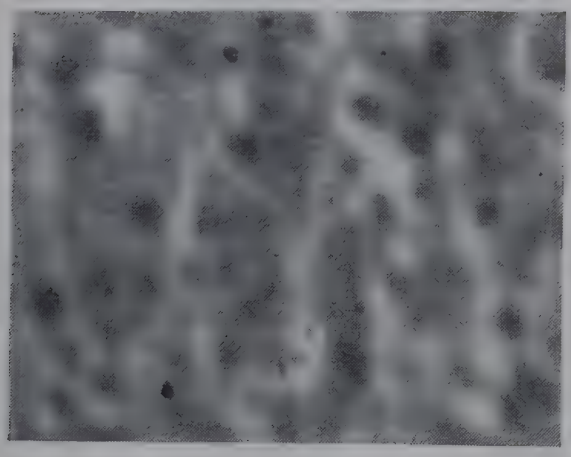
*Determination of the Equivalent Weight:* For this purpose a known quantity of humic acid suspension was taken in glass-stoppered pyrex bottles and treated with a known excess of 0.1N caustic soda solution. The contents were shaken and kept overnight. The excess of alkali was titrated conductometrically with 0.05 N sulphuric acid. The equivalent weight of humic acids was calculated from amount of alkali used up for neutralizing it (Table 2).

*Determination of Viscosity Number:* The procedure for the viscosity measurement of humic acid suspensions was almost similar to that of Visser[6]. For this measurement 0.1 per cent purified humic acid suspensions were taken in 1 per cent sodium fluoride and adjusted to pH 7.0 by caustic soda. The flow time of these suspensions

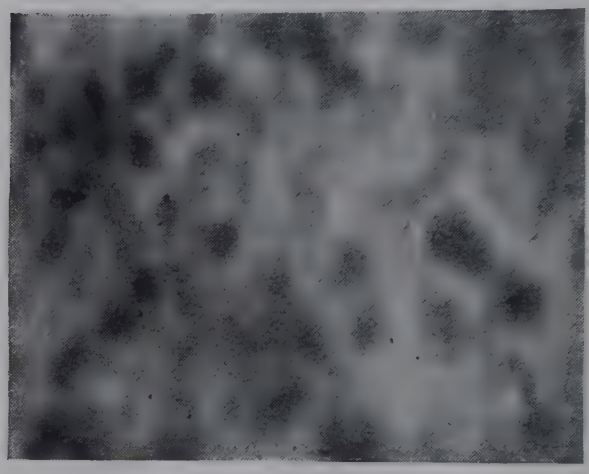
* Russian make type EM-5

Sample 1 (×1,80000)

Sample 2 (×1,81000)



Sample 3 (×2,28000)



Sample 4 (×1,05000)

Fig. 2—Electron Micrographs of the Humic Acid Samples.

as well as that of 1 per cent sodium fluoride solution was measured by an Ostwald viscometer at 26.5 ± 0.1°C using a stop watch calibrated to 1/10th of a second. The average value was taken for six consecutive determinations. The apparent viscosity was calculated from their flow time assuming the densities of the suspension as well as of sodium fluoride solution as equal. The viscosity number, which is $\frac{\text{Apparent viscosity}}{\text{concentration of suspension}}$, has been calculated from these values (Table 2).

TABLE 2

| Sl. No. | Sample | Equivalent Weight | Viscosity Number | Size of the Aggregates, Å |
|---|---|---|---|---|
| 1. | Black cotton | 131.5 | 0.0664 | 300 |
| 2. | Chinsura | 219.6 | 0.0888 | 130 |
| 3. | Ludhiana | 194.5 | 0.0873 | 150 |
| 4. | Ball clay | 157.7 | 0.0912 | 280 |

**Discussion**

The DTA thermograms of humic acids show two distinct peaks—one sharp endothermic at 90-110°C and the other exothermic in the region 290-400°C (Fig.1). According to Paulik et al[8] the endothermic peak is due to removal of adsorbed as well as colloidally-bound water, whereas the second one corresponds to decomposition of humic acid molecules. As the thermograms of different humic acids are similar, it is likely that their chemical structure is essentially of the same type. But a closer examination of the thermograms reveals that the exothermic peak temperature differs in different humic acids (Table 1). This may arise from some variation in the arrangement of different structural units of humic acids. It may be mentioned that in case of sample 4 which is isolated from a clay deposit in a coal bed the exothermic peak temperature is the highest of those studied here.

The electron micrographs (Fig.2) show the presence of small nearly spherical aggregates of varying sizes

(Table 2). The viscosity number (Table 2) is higher than the range of sphero-colloids (0.02-0.05) but well below that of linear colloids (0.5-2.0). The shape of the aggregates of sample 4 seems to be more elongated than that of soil humic acids. Its viscosity number is also the highest of these reported here.

The equivalent weights of the humic acids vary from 131.5 to 219.6 (Table 2) for the different samples. It is interesting to note here that the average size of the aggregates increases with the decrease of their equivalent weight. It may be concluded from this observation that the aggregate formation is more favoured in case of molecules having a higher number of acid groups.

**Acknowledgement**

Thanks are due to Dr. K. R. Chakravorty, General Manager, P & D Division, for his keen interest in this work. Thanks are also due to Dr. B. K. Banerjee and Sri K. C. Banerji of the Physical Research Wing for their valuable suggestions and to Sri S. K. Sharma for carrying out the conductometric titrations.

REFERENCES

1. Burges, A., *Sci. Proc. Roy. Dub. Soc.*, Ser. A. **1** (4) (1960), 53.
2. Steelink, A. C., *Geochim. Cos. Acta*, **28** (10) (1964), 1915.
3. Dragunova, A. E., *Guminovye. Ublo. kher. Sel 'SKO. Inst.*, (1957), 47; *Chem. Abstrs.*, **55** (1961), 1985b.
4. Seharpenseel, H. N., Koenig, E. & Menthe, E., *Z. Pflan. Dueng. Bodeuk.*, **106** (2) (1964), 134; *Chem. Abstr.* **62** (1965), 4561a.
5. Visser, S. A., *Soil. Sci.* **96** (1963), 353.
6. Idem, *J. Soil. Sci.*, **15** (1964), 202.
7. Kasatochkin, V. I., Kononova, M. M. and Zil'brand, O. I., *Doklady Akad. Nauk. SSSR*, **119** (1958), 785.
8. Paulik, F. and Weltner, M. W., *Acta. Chim., Acad. Sci. Hungar*, **16** (1958), 159.

# Corrosion of Sillimanite by Coal Ash Slag

By

S. K. Sharma, R. Choudhury, Sisir Mukherjee and H. Roy,

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

Corrosion of natural sillimanite block by the melt of coal ash admixed with fluxing agents, such as limestone and blast furnace slag, has been studied with reference to temperature, period of heating and structural characteristics of the refractory block. It has been observed that the slag melt corrodes the refractory in the temperature range of 1400°-1800°C in three different ways, viz. (1) interaction of the melt with the surface, (2) diffusion of melt through the body, and (3) penetration of melt along the cracks of the sillimanite block. Of these, the diffusion and penetration processes are operative only from 1600°C onward. The penetration of slag is possible due to structural failure of the refractory block at that temperature range. Further the interaction of the melt with sillimanite is found to accelerate with increasing temperature and period of heating.

Coal ash is known to corrode sillimanite refractory at high temperature[1,2]. With highly basic slag melts, sillimanite brick-lining of superheated steam boiler builds up thick incrustations[2]. In that case the characteristic reaction products are found to be gehlenite ($C_2AS$), dicalcium sillicate ($C_2S$), calcium aluminate (CA) and tetra calcium aluminoferrite ($C_4AF$), besides $CaSO_4$, glass, merwinite and spinel. But very little is known about the nature of corrosion of sillimanite by coal ash slag melt in plants like a slagging gas generator where the bed is usually made of this refractory. Further, the corrosion behaviour of sillimanite by coal ash slag has not so far been studied with respect to operating conditions, like temperature, period of heating, etc. These parameters affect the potential solubility, diffusion rate and electrochemical effect which are considered as the principal factors determining the degree of corrosion experienced by a refractory in a slagging gasifier[3].

Again the fusion temperature of a coal ash depends

upon its chemical composition. When this temperature is high, many of the fluxing agents are used for reducing it[4]. The nature of corrosion is, therefore, likely to be very much influenced by the character as well as amount of the fluxing agents.

It is with this view that the present study was undertaken to investigate into corrosion of natural sillimanite by molten coal ash slag with particular reference to the temperature and period of heating as well as structural characteristics of the sillimanite blocks.

**Experimental**

The slag was prepared by mixing 70 per cent coke with 30 per cent fluxing materials, comprising of blast furnace slag and limestone (in 3:2 ratio) and heating the mixture at about 1400°C in the slagg ng gas generator[5] set up by this Division. The molten mass was taken out and cooled rapidly in air. The fluid temperature of the slag was found to be 1300°C and its final composition (in per cent) was as follows[5]: $SiO_2$ 32.35, $Al_2O_3$ 27.30, $Fe_2O_3$ 1.20, CaO 36.85, MgO 2.00, $SO_3$ 0.30 and alkali nil.

Natural Assam sillimanite was selected as the refractory block. Small rectangular blocks of sillimanite (size $3'' \times 2'' \times 1''$) were cut out of a big block by a diamond rock cutter. The fusion temperature of this sample, as determined by the P.C.E. method,* was found to be $1860° \pm 10°C$.

*Corrosion Study of Sillimanite with Slag:* A small cavity was made in the sillimanite blocks so that each of them can accommodate 10 g. of slag. The blocks with slag were taken in a carbon resistance furnace and heated to 1400, 1600 and 1800°C for 2 and 6 hours with each temperature schedule. The time required to attain the operating temperature was 45-60 minutes. The samples were then cooled inside the furnace. During cooling, the time required to attain room temperature was about 3 hours in each case. The furnace atmosphere was found to be slightly reducing with carbon-monoxide during heating as well as cooling periods. The photographs of some of the corroded blocks are shown in Fig.1.

*Microscopic Studies:* The natural sillimanite as well as some of the corroded samples were examined by a polarizing microscope, using plane polarized light under a crossed nicol prism after making their thin sections (Fig.2). The magnification used in most of the cases was X45 except in one (X17.5).

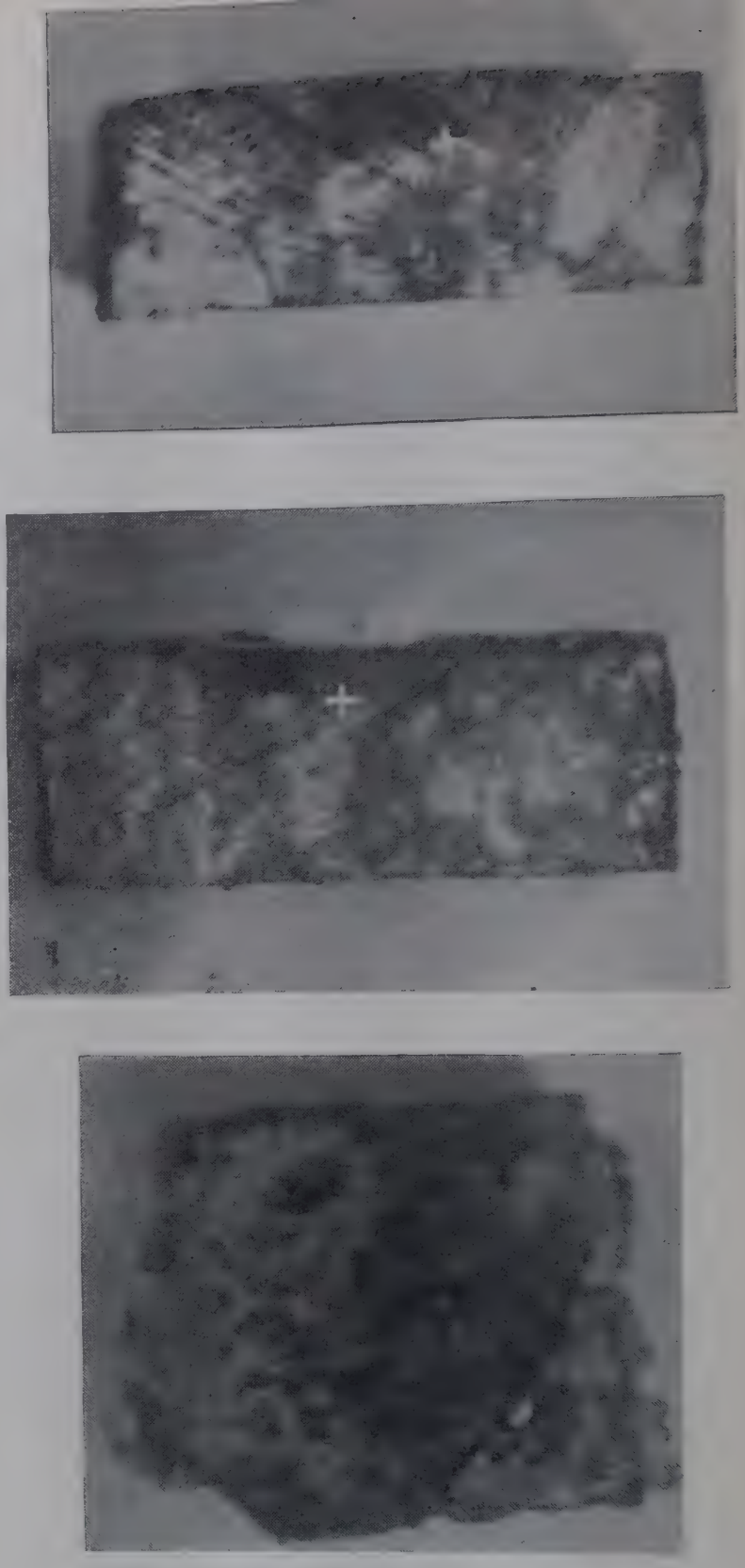



Fig. 1—Corroded Sillimanite Blocks.

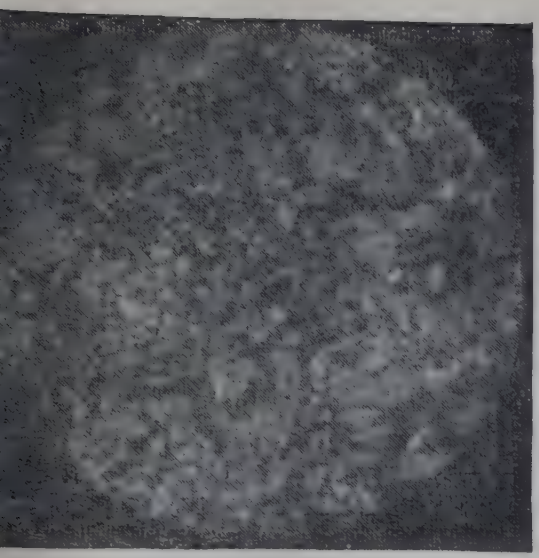
A—Sample heated to 1400°C for 2 hours showing interface of Slag and Refractory Block.

B—Sample heated to 1600°C for 2 hours showing interface of slag and Refractory Block.

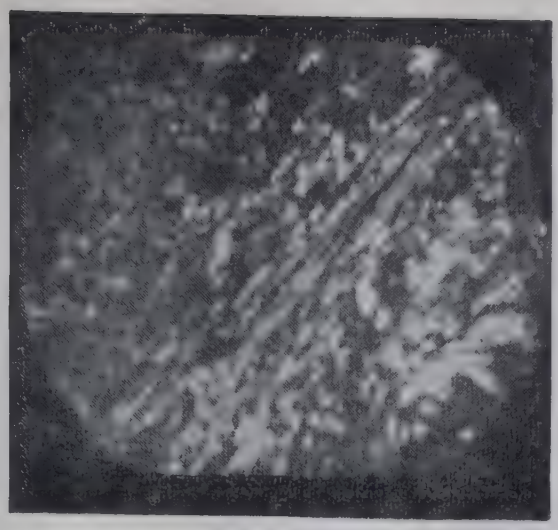
C—Sample heated to 1800°C for 6 hours showing corroded surface and penetration of Slag through the blocks.

+ Interface of Slag and Refractory.

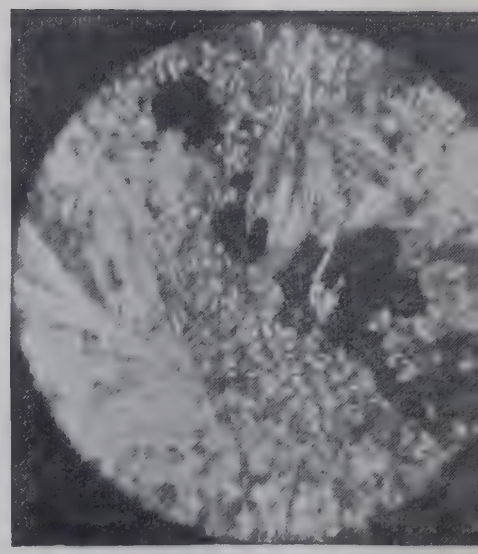
* ASTM C 24 (1966)



A

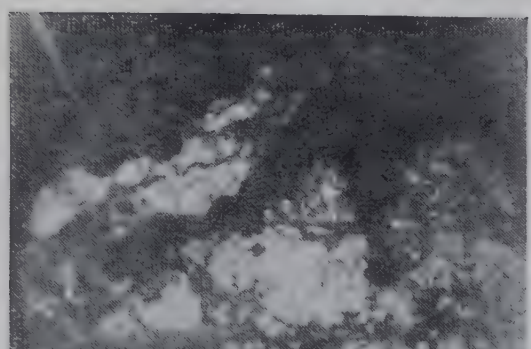


$B_1$

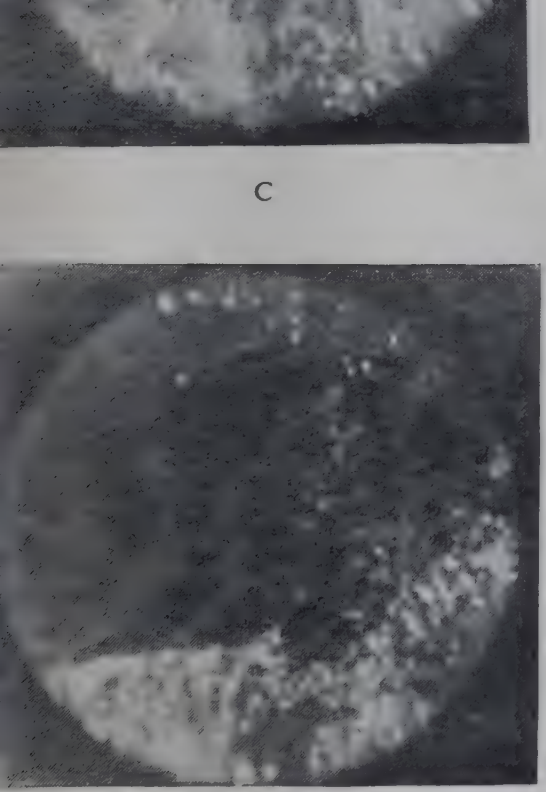


$B_2$

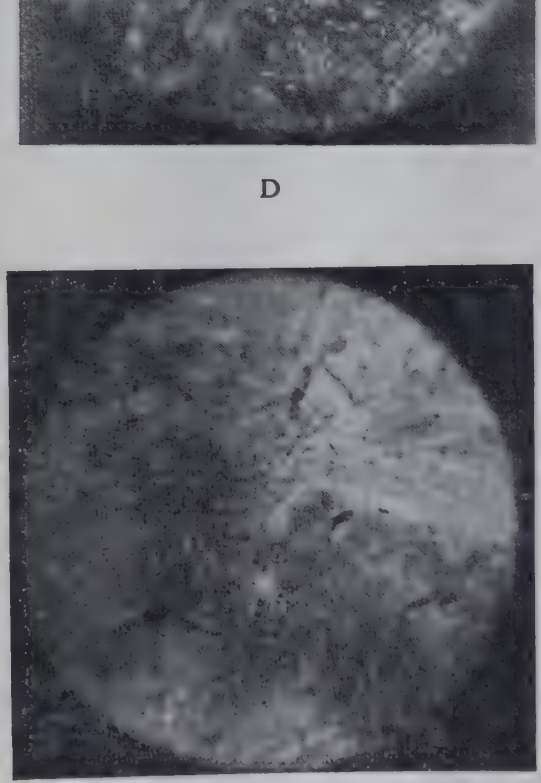
C



D



E



F

Fig. 2—Microphotographs of the Thin Sec
of Natural and Corroded Sillimanite Blo

A—Thin section showing fibrous sillim
mineral (×45 with plane polarised ligh

$B_1$—Thin section showing coarsely blended
columner kyanite mineral (×45 with
polarised light).

$B_2$—Thin section showing opaque zones of
spinels in sillimanite (×45 with
polarised light).

C—Thin section showing corroded interfa
sillimanite block heated to 1400°C f
hours. Needle shaped reaction product
evident at the interfact. (×45 with
polarised light).

D—Thin section showing diffusion of sla
sillimanite block heated to 1600°C f
hours (×17.5 with plane polarised ligh

E—Thin section showing selective diffusio
slag in the granular zone of sillim
block heated to 1600°C for 6 hours
with cross nickel and gypsum plate).

F—Thin section showing penetration of
along the cracks that appear in the
manite block heated to 1800°C fo
hours. Formation of new phases ar
the cracked surface is also conspic
(×45 with plane polarised light).

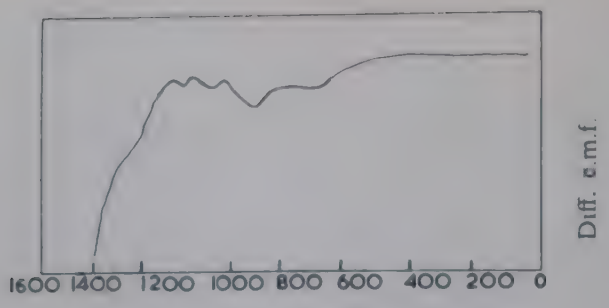



Fig. 3—DTA Thermogram of Sillimanite Powder (-85 mesh).

*Differential Thermal Analysis (DTA):* For this study, powdered sillimanite, (—85 mesh B.S.S.) was used as sample. The analysis was performed in a fully automatic Linseis DTA instrument using platinum sample-holders and Pt/Pt-Rh (13%) thermocouple in the temperature range of 30-1500°C (Fig.3). The heating rate was adjusted to 10°C/min. (approx.), and ignited aluminium oxide was used as the reference substance.

*Determination of Expansion of Sillimanite Blocks:* For measuring the expansion, the sillimanite blocks of size $1'' \times 1'' \times \frac{3}{8}''$ were heated at 1400, 1600 and 1750°C, for 1 hour in each case and cooled inside the furnace under identical conditions as mentioned earlier. The volume of each block before and after heating was measured by the mercury displacement method. Density of the sillimanite blocks was taken as 3.3 g./c.c. and the expansion (volume) was calculated (Fig.4).

*X-ray Analysis:* X-ray diffraction patterns of sillimanite, slag, the scrap from the interface of the corroded sillimanite and its slag phase after heating at 1600°C for 6 hours were taken by a Guinier focussing camera with monochromatic $CuK_{\alpha}$ radiation in a Philips PW1010 x-ray unit at 40KV and 20mA [Fig. 5, Table 1 (A, B)]. The time of exposure was 4 hours.

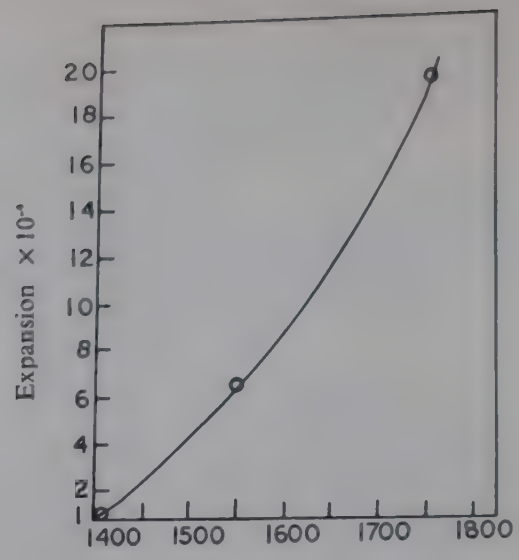



Fig. 4—Expansion of Sillimanite Block against Temperature.

**Results**

The microscopic study (Fig. 2, A) reveals that the sillimanite samples consist mainly of well crystalline sillimanite mineral. In contrast to the fibrous nature of this mineral small zones of coarsely bladed and columnar kyanite mineral are detected in the microphotograph as minor phase (Fig. 2, $B_1$). The evidence of a small proportion of iron-spinel has also been observed in the body (Fig. 2, $B_2$). DTA thermogram of its powdered sample (Fig. 3) reveals weak endothermic peaks at 710, 880, 1030 and 1100°C. The appearance of the first peak is due to the presence of pyrophyllite, whereas the remaining peaks are for mica type of minerals[6]. The presence of minor phases like kyanite and mica along with cristobalite, feldspar and serpentine mineral in sillimanite refractory has also been confirmed by x-ray diffraction method (Fig. 5, Table 1A). Further, the thermogram shows a continuous

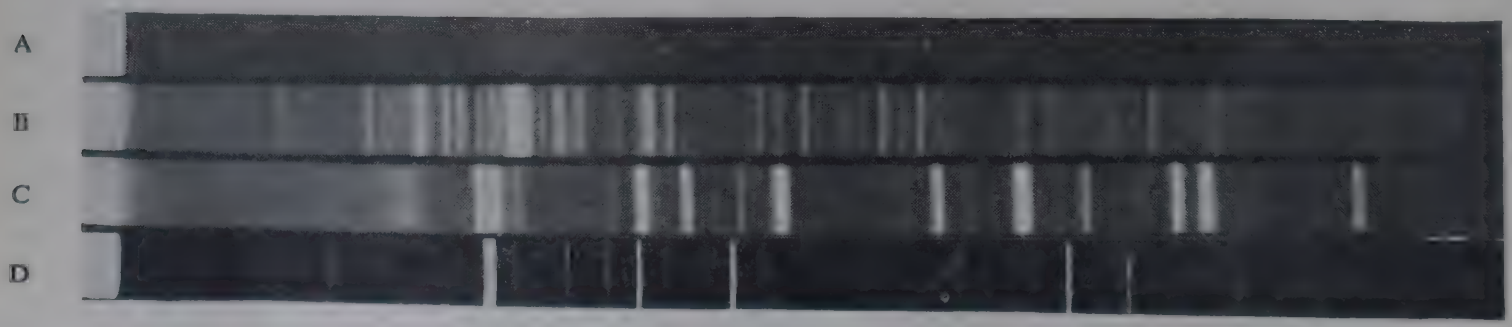



Fig. 5—X-ray Diffraction Patterns of Slag and Corroded Samples.
A—Slag heated to 1400°C; B—Slag phase of the corroded sillimanite heated to 1600°C for 6 hours; C—Interface of the corroded sillimanite heated to 1600°C for 6 hours; D—Natural sillimanite.

TABLE 1A—X-RAY DATA OF SILLIMANITE

| Sample | | Sillimanite[9] | | Kyanite | | Cristobalite[9] | | Feldspar (Albite) ASTM 1-0739 | | Serpentine[9] (Antigorite) | | Mica (Phlogopite) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| d (Å) | I | d (Å) | I | d (Å) | I | d (Å) | I | d (Å) | I | d (Å) | I | d (Å) | I |
| 10.0 | vvw | — | — | — | — | — | — | — | — | — | — | 10.1 | vs |
| 7.2 | vw | — | — | — | — | — | — | — | — | 7.3 | 400 | — | — |
| 6.35 | vvw | — | — | — | — | — | — | 6.4 | 8 | — | — | — | — |
| 5.38 | ms | 5.33 | 7 | — | — | — | — | — | — | — | — | — | — |
| 4.57 | w | 4.55 | 3 | — | — | — | — | — | — | — | — | — | — |
| 4.04 | w | — | — | — | — | 4.04 | 100 | 4.05 | 35 | — | — | — | — |
| 3.83 | vvw | — | — | — | — | — | — | 3.80 | 16 | — | — | — | — |
| 3.74 | m | 3.725 | 5 | — | — | — | — | — | — | — | — | — | — |
| 3.65 | vw | — | — | — | — | — | — | 3.66 | 25 | 3.63 | 300 | — | — |
| 3.41 | s | 3.401 | 9 | — | — | — | — | — | — | — | — | — | — |
| 3.37 | vs | 3.350 | 10 | — | — | — | — | — | — | — | — | 3.36 | vs |
| 3.20 | m | — | — | — | — | — | — | 3.20 | 100 | — | — | — | — |
| 3.19 | vw | — | — | 3.18 | 100 | — | — | — | — | — | — | — | — |
| 3.14 | vw | 3.139 | 1 | — | — | 3.138 | 12 | — | — | — | — | — | — |
| 3.02 | vvw | — | — | — | — | — | — | — | — | — | — | 3.04 | s |
| 3.00 | vw | 3.923 | 1 | — | — | — | — | — | — | — | — | — | — |
| 2.94 | w | — | — | — | — | — | — | 2.96 | 25 | — | — | — | — |
| 2.88 | ms | 2.875 | 7 | — | — | — | — | — | — | — | — | — | — |
| 2.84 | vvw | — | — | — | — | 2.845 | 14 | — | — | — | — | — | — |
| 2.675 | ms | 2.669 | 8 | — | — | — | — | — | — | — | — | — | — |
| 2.54 | s | 2.531 | 9 | 2.52 | 40 | — | — | 2.56 | 12 | 2.52 | 70 | — | — |
| 2.48 | vw | — | — | — | — | 2.489 | 18 | 2.44 | 14 | — | — | — | — |
| 2.42 | m | 2.414 | 7 | — | — | — | — | — | — | — | — | — | — |
| 2.37 | vvw | 2.360 | 1 | — | — | — | — | — | — | — | — | — | — |
| 2.34 | vvw | — | — | 2.35 | 40 | — | — | — | — | — | — | — | — |
| 2.30 | vw | 2.299 | 3 | — | — | — | — | 2.32 | 12 | — | — | — | — |
| 2.28 | m | 2.277 | 6 | — | — | — | — | — | — | | — | — | — |
| 2.20 | vs | 2.199 | 10 | — | — | — | — | — | — | — | — | — | — |
| 2.11 | ms | 2.108 | 6 | — | — | — | — | 2.13 | 12 | — | — | — | — |
| 2.085 | w | 2.086 | 3 | — | — | — | — | — | — | — | — | — | — |
| 1.98 | vw | 1.981 | 2 | — | — | — | — | — | — | — | — | — | — |
| 1.96 | vw | 1.960 | 2 | 1.96 | 40 | — | — | — | — | — | — | — | — |
| 1.91 | vvw | — | — | 1.93 | 50 | — | — | 1.90 | 12 | — | — | — | — |
| 1.87 | ms | 1.87 | 5 | — | — | — | — | — | — | — | — | — | — |
| 1.83 | ms | 1.828 | 6 | — | — | — | — | 1.83 | 18 | — | — | — | — |
| 1.81 | vvw | 1.813 | 2 | — | — | — | — | — | — | — | — | — | — |
| 1.782 | vw | 1.781 | 3 | — | — | — | — | — | — | — | — | — | — |
| 1.705 | m | 1.703 | 5 | — | — | — | — | — | — | — | — | — | — |
| 1.69 | m | 1.689 | 6 | — | — | — | — | — | — | — | — | — | — |
| 1.68 | ms | 1.677 | 7 | — | — | — | — | — | — | — | — | — | — |
| 1.595 | ms | 1.594 | 4 | — | — | — | — | — | — | — | — | — | — |
| 1.568 | ms | 1.566 | 6 | — | — | — | — | — | — | — | — | — | — |
| 1.560 | vvw | 1.559 | 3 | — | — | — | — | — | — | — | — | — | — |
| 1.537 | vw | 1.533 | 2 | — | — | — | — | — | — | — | — | — | — |
| 1.518 | s | 1.516 | 9 | — | — | — | — | — | — | — | — | — | — |
| 1.45 | vw | 1.450 | 4 | — | — | — | — | 1.46 | 16 | — | — | — | — |
| 1.44 | ms | 1.440 | 7 | — | — | — | — | 1.43 | 16 | — | — | — | — |
| 1.418 | vw | 1.418 | 2 | — | — | — | — | — | — | — | | | |
| 1.392 | w | 1.392 | 5 | — | — | — | — | — | — | — | — | — | — |
| 1.37 | vvw | — | — | 1.37 | 75 | — | — | — | — | — | — | — | — |

I=Relative intensity, s—strong, vs—very strong, ms—medium strong, m—medium, w—weak, vw—very weak, vvw—very very weak.

| Slag (as it is) | | Slag Phase Heated to 1600°C (taken from corroded Sillimanite) | | Surface of Sillimanite heated to 1600°C | | ($CAS_2$) ASTM Card-9-464 and 2-512 | | ($C_2AS$) ASTM Card 4-0690 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| d (Å) | I | d (Å) | I | d (Å) | I | d (Å) | I | d (Å) | I | d (Å) | I | d (Å) | I | d (Å) | I |
| | | 6.5 | vw | | | 6.56 | 40 | | | | | 5.37 | 70 | | |
| | | | | 5.4 | vw | | | | | | | | | | |
| | | 4.70 | w | 4.75 | vvw | 4.70 | 60 | | | | | | | 4.26 | 35 |
| | | | | 4.25 | vvw | | | 4.23 | 20 | | | | | | |
| 4.26 | w | | | | | | | | | | | | | | |
| | | 4.02 | ms | 4.03 | vw | 4.04 | 70 | | | | | | | | |
| | | 3.91 | vw | | | 3,92 | 50 | | | | | | | | |
| | | 3.80 | m | 3.78 | vvw | 3.78 | 70 | | | | | | | | |
| | | 3.62 | m | 3.60 | vvw | 3.62 | 70 | | | | | | | | |
| | | 3.48 | w | 3.50 | ms | 3.46 | 50 | | | 3.48 | 60 | | | | |
| | | | | 3.41 | vw | | | | | | | 3.418 | 90 | | |
| | | | | | | | | | | | | 3.383 | 100 | | |
| | | 3.36 | m | 3.35 | m | 3.36 | 60 | | | | | | | 3.343 | 100 |
| 3.34 | s | | | | | | | | | | | | | | |
| | | 3.27 | m | 3.25 | vw | 3.26 | 80 | | | | | | | | |
| | | 3.20 | s | 3.20 | vw | 3.20 | 100 | | | | | | | | |
| | | 3.14 | m | | | 3.17 | 80 | | | | | | | | |
| | | 3.04 | vw | | | 3.04 | 60 | 3.06 | 60 | | | | | | |
| | | 2.95 | w | | | 2.95 | 70 | | | | | | | | |
| | | | | 2.90 | vvw | | | | | | | 2.878 | 70 | | |
| 2.85 | w | 2.85 | vw | | | 2.83 | 60 | 2.85 | 100 | | | | | | |
| | | 2.83 | vw | | | | | | | | | | | | |
| | | 2.65 | w | 2.68 | vw | 2.65 | 60 | | | | | 2.686 | 80 | | |
| | | 2.55 | w | 2.55 | s | | | | | 2.55 | 85 | 2.538 | 90 | | |
| | | 2.52 | m | | | 2.52 | 70 | | | | | | | | |
| 2.45 | vvw | 2.45 | m | | | 2.50 | 70 | 2.43 | 70 | | | | | | |
| | | 2.38 | vvw | 2.39 | m | | | 2.40 | 70 | 2.38 | 32 | | | | |
| | | 2.32 | vvw | | | | | | | | | | | | |
| 2.28 | vvw | | | 2.29 | vvw | | | 2.30 | 70 | | | 2.289 | 80 | | |
| | | 2.26 | vvw | | | | | | | | | | | | |
| | | | | 2.20 | vvw | | | | | | | 2.201 | 90 | | |
| | | 2.15 | m | | | 2.14 | 50 | | | | | | | | |
| 2.10 | vvw | 2.08 | w | | | 2.10 | 20 | 2.04 | 60 | | | | | | |
| | | | | 2.09 | s | | | | | 2.085 | 100 | 2.115 | 80 | | |
| | | 2.02 | w | | | | | | | | | | | | |
| | | 1.93 | w | 1.96 | vvw | 1.93 | 20 | | | | | | | | |
| | | 1.88 | vw | | | | | | | | | | | | |
| | | | | 1.87 | vvw | | | 1.87 | 50 | | | | | | |
| | | 1.84 | w | | | 1.84 | 40 | 1.85 | 50 | | | | | | |
| 1.81 | vw | | | | | | | 1.81 | 60 | | | | | 1.817 | 17 |
| | | 1.80 | w | | | 1.80 | 30 | | | | | | | | |
| | | 1.77 | w | | | 1.76 | 30 | | | | | | | | |
| 1.76 | vw | | | | | | | 1.75 | 100 | | | | | | |
| | | | | 1.74 | ms | | | | | 1.741 | 45 | | | | |
| | | 1.72 | vvw | | | 1.71 | 10 | | | | | 1.693 | 70 | | |
| | | | | 1.69 | vvw | | | | | | | | | | |
| | | 1.68 | vvw | | | | | | | | | | | | |
| | | 1.60 | vw | 1.60 | s | | | 1.61 | 30 | 1.601 | 85 | | | | |
| | | 1.56 | vw | | | | | | | | | | | | |
| | | | | 1.55 | vw | | | 1.55 | 20 | 1.546 | 2 | | | | |
| | | | | 1.51 | w | | | 1.52 | 70 | 1.511 | 8 | 1.522 | 90 | | |
| | | 1.46 | w | | | 1.45 | 20 | | | | | | | | |
| | | | | 1.44 | vvw | | | 1.44 | 50 | | | 1.439 | 80 | | |
| | | | | 1.405 | ms | | | | | 1.405 | 35 | | | | |
| | | 1.39 | vw | | | 1.39 | 30 | | | | | | | | |
| | | | | 1.375 | ms | | | | | 1.374 | 50 | | | | |
| | | 1.37 | vw | | | | | 1.37 | 50 | | | | | | |
| | | 1.36 | vw | | | 1.36 | 20 | 1.36 | 60 | | | | | | |
| | | | | 1.337 | vvw | | | | | 1.336 | 2 | | | | |
| | | | | 1.275 | vvw | | | | | 1.276 | 2 | | | | |
| | | | | 1.239 | w | | | | | 1.238 | 15 | | | | |
| | | | | 1.234 | w | | | | | 1.234 | 10 | | | | |
| | | | | 1.190 | vw | | | | | 1.190 | 5 | | | | |
| | | | | 1.148 | vw | | | | | 1.148 | 5 | | | | |
| | | | | 1.124 | w | | | | | 1.123 | 7 | | | | |
| | | | | 1.100 | w | | | | | 1.099 | 8 | | | | |

downward trend starting at about 1200°C. It is already know that the decomposition of sillimanite starts at 1550°C and is complete at 1625°C and that of kyanite starts at 1100°C and is complete at 1410°C. The temperature of complete decomposition, however, varies with the rate of heating and size of grains[7]. As such, the downward trend of the thermogram at 1200°C is not due to decomposition of sillimanite (Fig.3). It may, therefore, be inferred that admixed micaceous and feldspathic minerals of the refractory start fusing at that temperature range along with the decomposition of kyanite. Again, it has been observed that the sillimanite block on heating expands to a very small extent upto 1600°C but comparatively to a large extent above that temperature (Fig.4). The expansion of sillimanite and kyanite is due to its mullitization, as a result of which there is a change in density from 3.3 (or 3.6-3.7 in case of kyanite) to 3.16 g./c.c[7]. The results show that the expansion is abrupt in the region of 1600-1800°C.

X-ray examination of the slag sample rapidly cooled in air after fusion at 1300°C shows that free quartz and gehlenite ($C_2AS$) along with glassy mass are the constituent (Fig. 5, Table 1B). This observation is in accordance with the Rankin's $CaO\text{-}Al_2O_3\text{-}SiO_2$ phase diagram[8].

The products of corrosion of sillimanite with slag scrapped from the interface as well as slag phase have also been identified by x-ray diffraction method (Fig.5, Table 1B). Presence of constituents, like $C_2AS$ and $CAS_2$ ($CaO$, $Al_2O_3$, $2SiO_2$, triclinic), in the slag phase whereas those of $CAS_2$, mullite and $\alpha\text{-}Al_2O_3$ in the interface have been idenified. The Presence of $\alpha\text{-}Al_2O_3$ has also been detected in the slag phase but unlike the latter its concentration is very low. It may, therefore, be assumed that this constituent has come from the interface by diffusion process.

**Discussion**

The coal ash slag corrodes the sillimanite blocks in the temperature range 1400-1800°C in three different ways viz. (1) interaction of melt with the surface (ii) diffusion of melt through the body and (iii) penetration of melt along the cracks of the sillimanite block.

The new products which appear at the interface due to interaction of slag melt with the sillimanite are found to be $\alpha\text{-}Al_2O_3$, mullite and $CAS_2$ whereas $CAS_2$ in the slag phase. Mullite at the interface may be formed due to interaction of the slag with the sillimanite or appear from the refractory itself. This shows that the initial composition of the slag, which is in the $C_2AS$ zone, has been shifted to $CAS_2$ zone in the Rankins phase diagram due to interaction, thus dissolving silica ($SiO_2$) and alumina ($Al_2O_3$) from the refractory block. The presence of $\alpha\text{-}Al_2O_3$ in the reaction product indicates that the slag melt has been enriched with silica ($SiO_2$) constituent. It is, therefore, likely that the melt preferentially dissolves silica from the surface leaving alumina, which crystallizes to its $\alpha$-form at that operating temperature.

A visual inspection of the corroded blocks (Fig.1) as well as qualitative microscopic examination of the slag-sillimanite interface (Fig.2) reveals that the depth of corrosion increases with increasing temperature and heating period. The surface corrosion is not significant at 1400°C even when the sample is heated for 6 hours, whereas it is quite distinct at 1600°C, and more prominent at 1800°C. Similarly, the diffusion of slag into the body of sillimanite block is not also significant at 1400°C in spite of the fact that the sintering of sillimanite powder starts at about 1200°C as is evident from its DTA curve (Fig.3). But this duffusion is quite prominent at higher temperatures (Fig. 2, D) and with longer period of heating (Fig. 2, E). The microphotographs reveal that this diffusion of melt through the body of the refractory is selective in nature. It is more distinct in the granular zone of the refractory block than that in the fibrous zone (Fig.2, E). Although the exact reason for the development of the granular nature in the heated sillimanite block cannot be ascertained from the results, it may be inferred that this zone may be developed due to mullitization of kyanite, which is usually present in sillimanite blocks.

The penetration of the melt inside the refractory body through the cracks has also been observed (Fig. 2, F). These are particularly prominent in samples heated to 1800°C. The formation of such cracks in the block is due to rapid expansion of sillimanite and kyanite. This is evident from the expansion of the block which has been found to be very high in the region of 1600 to 1800°C in comparison to that of the lower temperature range (Fig.4).

It is also evident form the microphotographs (Fig. 2, C and F) that some new phases, which are quite different from those of the sufrace, appear along the sides of the cracks. Corrosion in these zones seems to be more intense than on the surface. It is quite likely that some of the minor constituents fuse at that temperature and creep through the cracks, thus mixing with the slag melt and changing its composition. As a result, different reaction products are formed when the melt attacks the cracked surface.

**Acknowledgement**

Thanks are due to Dr. K. R. Chakravorty, General Manager, P&D, Division, for his keen interest in this investigation. Thanks are also due to Dr. B. K. Banerjee and Sri K. C. Banerji, of the Physical Research Wing of the same Division, for their active encouragement.

REFERENCES

1. Morpurgo, A., *Chim. Indust.*, **43** (1961), 1259; Abstr. from Fuel Abst., **4** (1963), 3242.
2. Batti, P., *Ceramica*, **17** (8) (1962), 51.
3. Boow J., *Coal Res. In CSIRO*, Bull. No. 30, Nov. 1966, 12.
4. Dutta, B. K., Rai, B. and Chakravorty, K. R., *J. Sci. & Indus. Res.*, **19B** (1960), 206.
5. Ghosh, S. C., Chatterjee, B. and Joshi, M. L., *Technol*, **1** (4) (1964), 3.
6. Ivanova, V. P., *Apiski Vse. Min., Obs.* **90** (1961), 50.
7. Norton, F. H., *Refractories* (McGraw. Hill Book Co. Inc., New York), 1949. 193.
8. Rankin, G. A. and Wright, F. E., *Am. J. Sc.*, 39, (1915).
9. Brown, G., *The X-ray Identification and Crystal Structures of Clay Minerals* (Min. Soc., London), 1961

# Physico-Chemical and Mineralogical Investigation of Various Indian Soils

By

S. C. Chatterjee and B. K. Dhar,*

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

Some typical soils of India have been analysed to study the physico-chemical properties in relation to soil texture, nature and distribution of clay mineral and fertility status. Differential thermal, x-ray diffraction and chemical analyses of the soil clays show that most of the soils contain illite as a major phase, and quartz, montmorillonite, kaolinite as minor phases with the exception of Amraoti soil, which contains montmorillonite as a major phase and kaolinite in the clay as a minor phase. There is variation in cation-exchange capacity, nutrient status and soil texture. These variations are due to variation in the parent material. The sharp basal line at 14-15 Å, observed in most of the clays, may be due to the presence of montmorillonite as an organo-clay complex.

Soil being the medium for crop production needs comprehensive investigations about its physico-chemical properties in relation to soil fertilizer reaction and crop requirements. Several such investigations on Indian Soils have been done previously [1–5].

Soils vary widely in texture, fertility, mineral contents from place to place, but no precise information of such characteristics of Indian soil are available. Thus, it was necessary to investigate the nature and distribution of clay minerals, soil formation and fertility status of some Indian soils of different regions.

## Experimental

Representative soil samples from 0-9″ depth were collected from Ludhiana (Punjab), Allahabad (U.P.), Jodhpur (Rajasthan), Amroati (Maharashtra), I.A.R.I. (New Delhi), Dinhata (Coochbehar, W. Bengal), Sindri. The clay fractions of these soils were separated by the usual method of mechanical analysis[6] using ammonium hydroxide for dispersion and then converted into H-clays by treatment with 0.01 (N) HCL. Portion of the clays were cleaned by Jeffries method[7].

The total nitrogen and organic carbon were determined by the A.O.A.C. and Walkley and Black's methods respectively[6]. The pH of the soil was determined on 1:2.5 soil water suspension by a glass electrode

* Present Address: Ministry of Food & Agriculture, Krishi Bhavan, New Delhi.

photovolt pH meter. The analysis of HCL extract of the soils for total $R_2O_3$, $Fe_2O_3$, CaO, MgO, $K_2O$ and $P_2O_5$ was carried out by the A.E.A. method. Cation-exchange capacity and exchangeable bases were determined by Piper's method[6]. The clay fraction was fused with sodium carbonate and analysed for its chemical composition[6].

X-ray diffraction analysis of the soil clays was carried out by the powder method using filtered $CuK_\alpha$ and $FeK_\alpha$ radiation. The identification was made by the usual method of Hanawalt et al[8]. Differential thermal analysis of the soil clays was conducted by using a standard sample of calcined alumina.

**Results and Discussion**

Both the physical and chemical data are given in Tables 1-4.

The soils under investigation are all of alluvial origin except the one of Jodhpur (Rajasthan), which is a desert soil.

The mechanical analysis of the soil samples of alluvial origin show that they are rich in sand, with the exception of the Dinhata soil which is rich in silt probably due to regular silt deposition by flood waters. Sindri red soil shows high clay content (29 per cent) which may have been formed due to the weathering of the coarser fraction. Amroati soil is the alluvium of the Purna valley[9], having 27 per cent clay.

Both Amroati and Dinhata soils are rich in organic matter, total nitrogen and sesquioxide contents (Tables 2 & 3). Cation exchange capacity and pH of Amroati soil are high (52.90 m.e./100 g. and pH 8.3). The soil was originally a weathered basalt on which probably alluvium was deposited. Dinhata soil has low cation-exchange capacity and a low pH (4.7 m.e./100g. and pH 4.5) and is poor in calcium and magnesium contents. This is probably due to the heavy floods which occur frequently, thereby removing the bases and leaving the soil acidic.

Ludhiana and New Delhi soils are *Gangetic* alluvium having almost the same physico-chemical properties and showing a similar soil formation. New Delhi soil is rich in sand; Ludhiana soil is also rich in sand but its clay content is double than that of the New Delhi soil. The pH of New Delhi soil is 7.7 whereas that of Ludhiana soil is 8.4; both contain some amount of calcium carbonate. These variations may be due to the variation in drainage.

Allahabad soil, which is a newer *Gangetic* alluvium, contains very small amount of organic matter and total nitrogen and is low in cation-exchange capacity. It is rich in total $P_2O_5$, $K_2O$ and MgO contents and has some amount of calcium carbonate.

Sindri red soil has been developed from weathering of rocks and due to erosion and continuous weathering action of the top layer; it is deficient in organic matter, total nitrogen and total bases. It has a high sesquioxide content in which iron is the major phase. The soil is near neutral.

Jodhpur soil is mainly sandy with small amounts of silt and clay. It is very poor in organic matter, total nitrogen and sesquioxide. It's pH is high (8.3), while the cation-exchange capacity is very low.

The chemical analysis of the clay fractions of all the soils, except that of Amroati, shows as high amount of potassium content and a cation-exchange capacity varying from 49.30 to 20.00 m.e./100 g. of soil. This is probably due to the predominance of illite type clay mineral. On the other hand, Amroati soil clay has low potassium content but high cation-exchange capacity (85 m.e./100 g.), showing the predominance of montmorillonite type clay mineral. Grim[10] has suggested cation-exchange capacity of a number of clay minerals.

The mineralogical composition of the soil clays, as determined by x-ray diffraction and differential thermal analysis (Table 1), shows the presence of illite as a major phase with small amounts of quartz, montmorillonite and kaolinite as the minor phase in almost all soils, except Amroati soil in which montmorillonite is present as a predominant clay mineral.

The soils, containing almost the same amount of illite-type clay mineral, show some variation in cation-exchange capacity amongst each other, which may be due to quartz, kaolinite and montmorillonite present in various amounts in the minor phases. The presence of quartz and kaolinite decreases the cation-exchange capacity of the clay, whereas montmorillonite increases the cation-exchange capacity of the soil clays.

It is interesting to note that the x-ray diffraction patterns of all the soil clays, except that of Allahabad soil clay, shows a very sharp basal line at 14-15 Å (Table 1) besides the characteristic basal line of illite. Several workers[11–13] have reported that whenever there is presence of an organo-clay complex of montmorillonite, there is variation in spacing and intensity of basal reflection of montmorillonite, usually the intensity of the basal reflection is increased due to complex formation. D.T.A. thermograms reveal that all the clay samples exhibit the presence of organic matter with the exception of the Allahabad soil. Obviously

TABLE 1—D. T. A. Analysis & X-ray Diffraction Analysis of Some Soil Clay Samples

| Sl. No. | Soil Clays | D. T. A. Analysis | | Inference | X-ray Analysis | Inference |
|---|---|---|---|---|---|---|
| | | Endothermic peak | Exothermic peak | | Spacings in Å | |
| 1. | Amroati Black Cotton Soil Clay | 100 (strong)<br>575 (weak)<br>620 (medium)<br>710 (weak)<br>815 (weak) | 340 (medium bulge)<br>840 (medium bulge)<br>920 (medium bulge) | Montmorillonite mainly, Kaolinate & organic matter is present in small amount. | 14.1 (S), 4.95 (S), 4.45 (V.S), 2.56 (W), 1.677 (V.W), 1.507 (S), 1.299 (W), 1.257 (V.W) | Montmorillonite mainly |
| 2. | I.A.R.I., New Delhi Soil Clay | 130 (strong)<br>575 (medium)<br>590 (very weak)<br>620 (weak)<br>710 (weak bulge)<br>850 (weak bulge) | 340 (weak)<br>900 (weak) | Illite mainly, quartz is present. Montmorillonite & organic matter is also present | 15,00 (W), 9.647 (S), 4.467 (V.S), 4.141 (V.W), 3.454 (V.W), 3.307 (V.S), 2.331 (S),2.428 (V.W),2.377 (V.W), 2.246 (V.W), 1.665 (V.W), 1.645 (V.W), 1.484 (W.) | Illite mainly, quartz is present. Motmorrilonite may be present. |
| 3. | Allahabad Soil Clay | 100 (strong)<br>240 (very weak)<br>580 (medium)<br>710-740 (weak)<br>830 (weak) | 930 (medium) | Illite mainly, quartz is present. Kaolinite and Montmorillonite is also present | 18.46 (Diffuse), 10.09 (S), 7.053 (V.W), 4.57 (W), 4.61 (V.W), 3.331 (W), 3.171 (V.W), 3.567 (W), 2.413 (W), 2.256 (V.W), 2.129 (V.W), 1.979 (V.W), 1.799 (V.W), 1.528 (V.W), 1.492 (W). | Illite mainly, quartz is present. Montmorillonite and kaolinite may be present. |
| 4. | Sindri Red Soil Clay | 130 (strong)<br>590 (strong)<br>710 (weak) | 340 (weak)<br>890 (weak) | Illite mainly, quartz, Montmorillonite and organic matter is also present. | 15.00 (W), 9.811 (W), 7.409 (V.W), 4.514 (S), 4.152 (W), 3.508 (W), 3.307 (W), 3.087 (V.W), 2.580 (W), 2.424 (W), 2.246 (V.W), 1.775 (V.W), 1.665 (V.W), 1.645 (V.W), 1.538 (W), 1.484 (V.W). | Illite mainly, quartz, Kaolinite and Montmorillonite may be present. |
| 5. | Jodhpur Sandy Soil Clay | 135 (strong)<br>590 (medium)<br>830 (weak) | 390 (weak)<br>750 (strong)<br>900 (medium) | Illite mainly, quartz is present. | 11.47 (B.B), 4.99 (W), 4.50 (S), 3.36 (S), 2.86 (W), 2,58 (S), 2.46 (V.W), 2.37 (V.W), 2.00 (V.W), 1.82 (V.W), 1.50 (S), 1.377 (V.W). | Illite mainly, quartz, is present. |
| 6. | Ludhiana Soil Clay | 135 (strong)<br>590 (medium)<br>830 (weak) | 390 (weak)<br>720 (strong)<br>910 (medium) | Illite mainly, organic matter and quartz is present. Kaolinite may be present. | 15.00 (W), 10.09 (S), 7.150 (V.W), 4.956 (V.W), 4.467 (V.X.S), 4.297 (W), 3.927 (V.W), 3.676 (V.W), 3.454 (V.W), 3.307 (V.S), 3.215 (V.W), 2.970 (V.W), 2.667 (V.W), 2.554 (S), 2.424 (V.W), 2.337 (V.W), 2.225 (V.W), 2.186 (V.W), 2.129 (V.W), 1.824 (W), 1.665 (V.W). | Illite mainly and quartz is present. Montmorrillonite and Kaolinite may be present. |
| 7. | Dinhata Soil Clay | 120 (big)<br>230 (weak)<br>560 (medium) | 830 (big) | Illite mainly, organic matter and quartz is present. | 14.30 (S), 9.647 (S), 6.945 (W), 4.467 (S), 4.218 (W), 3.861 (W), 3.736 (W), 3.508 (W), 3.307 (V.S), 3.171 (W), 3.007 (W), 2.862 (V.W) 2.794 (V.W), 2.554 (S), 2.449 (W), 2.377 (W), 2.246 (V.W), 2.129 (W), 2.124 (W), 1.877 (V.W), 1.824 (V.W), 1.775 (V.W), 1.752 (V.W), 1.665 (W), 1.600 (V.W), 1.563 (V.W), 1.538 (W), 1.484 (W). | Illite mainly, quartz is present. Montmorillonite and kaolinite may be present. |

*Note:* V.S.=Very strong, S=Strong, B.B.=Broad band, W=Weak, V.W=Very weak.

TABLE 2—PHYSICAL PROPERTIES OF SOILS

| Sl. No. | Soils | Moisture, % | Loss on Ignition % | Sand, % | Silt, % | Clay, % | C.E.C. m.e./100 g. | Exchangeable Calcium, m.e./100 g. | Exchangeable Magnesium, m.e./100 g. | Exchangeable Potassium, m.e./100 g. | $CaCO_3$, % | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Amroati black loam (0-9″) | 10.45 | 10.22 | 31 | 22 | 27 | 52.90 | 34.45 | 5.20 | 1.20 | 10.0 | 8.3 |
| 2. | I.A.R.I. New Delhi Sandy loam alluvial (0-9″) | 1.60 | 3.28 | 61 | 8 | 16 | 10.56 | 6.10 | 0.80 | 1.59 | 4.0 | 7.7 |
| 3. | Allahabad Sandy alluvial (0-9″) | 1.05 | 5.13 | 80 | 7 | 7 | 3.37 | 1.55 | 0.18 | 1.04 | 4.0 | 8.2 |
| 4. | Sindri red clay loam (0-9″) | 2.24 | 5.07 | 58 | 5 | 29 | 12.60 | 4.15 | 1.15 | 1.53 | Nil | 6.6 |
| 5. | Jodhpur Sandy (0-9″) | 0.37 | 1.47 | 83 | 12 | 4 | 3.29 | 1.50 | Nil | 1.20 | 0.7 | 8.3 |
| 6. | Ludhiana alluvial Sandy loam (0-9″) | 1.29 | 3.69 | 70 | 9 | 16 | 8.22 | 3.75 | 0.90 | 1.25 | 1.5 | 8.4 |
| 7. | Dinhata alluvial silty loam (0-9″) | 1.13 | 5.89 | 22 | 57 | 14 | 4.70 | Nil | Nil | Nil | Nil | 4.5 |

TABLE 3—CHEMICAL COMPOSITION OF SOILS, %
(Oven-dry Basis)

| Sl. No. | Soils | HCl-Insoluble | Organic Carbon | Total N | $Fe_2O_3$ | $Al_2O_3$ | CaO | MgO | $K_2O$ | $P_2O_5$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Amroati black loam (0-9″) | 53.60 | 0.35 | 0.08 | 9.28 | 11.61 | 7.21 | 1.72 | 1.66 | 0.13 |
| 2. | I.A.R.I. New Delhi Sandy loam alluvial (0-9″) | 85.10 | 0.33 | 0.07 | 2.62 | 3.48 | 3.36 | 0.38 | 1.54 | 0.10 |
| 3. | Allahabad Sandy alluvial (0-9″) | 82.05 | 0.37 | 0.05 | 3.47 | 3.19 | 2.91 | 1.02 | 1.93 | 0.16 |
| 4. | Sindri red clay loam (0-9″) | 77.65 | 0.37 | 0.04 | 5.27 | 7.11 | 0.36 | 0.18 | 1.46 | 0.07 |
| 5. | Jodhpur Sandy (0-9″) | 94.21 | 0.18 | 0.03 | 1.44 | 1.07 | 0.58 | 0.17 | 0.88 | 0.12 |
| 6. | Ludhiana alluvial Sandy loam (0-9″) | 85.21 | 0.43 | 0.07 | 3.04 | 3.95 | 0.82 | 0.49 | 1.50 | 0.13 |
| 7. | Dinhata alluvial silty loam (0-9″) | 85.52 | 0.60 | 0.11 | 6.06 | 5.06 | 0.17 | Nil | 1.30 | 0.05 |

TABLE 4—CHEMICAL COMPOSITION OF CLAY FRACTION

| Sl. No. | Description | $SiO_2$, % | $Fe_2O_3$, % | $Al_2O_3$ % | $K_2O$, % | $SiO_2/R_2O_3$ | Cation Exchange Capacity, m.e./100 g. |
|---|---|---|---|---|---|---|---|
| 1. | Amroati Black Cotton Soil (0-9″) Clay | 47.24 | 15.70 | 21.86 | 2.53 | 2.50 | 85.00 |
| 2. | I.A.R.I. New Delhi Soil (0-9″) Clay | 43.91 | 17.20 | 18.30 | 4.38 | 2.50 | 49.30 |
| 3. | Allahabad Soil (0-9″) Clay | 41.68 | 20.35 | 8.02 | 7.12 | 3.40 | 33.24 |
| 4. | Sindri red Soil (0-9″) Clay | 39.44 | 16.70 | 23.46 | 2.52 | 2.00 | 37.00 |
| 5. | Jodhpur Sandy Soil (0-9″) Clay | 46.00 | 11.20 | 9.10 | 5.62 | 4.80 | 16.50 |
| 6. | Ludhiana Soil (0-9″) Clay | 42.50 | 23.80 | 14.28 | 6.83 | 2.40 | 35.60 |
| 7. | Dinhata Soil (0-9″) Clay | 41.64 | 17.40 | 16.96 | 6.42 | 2.52 | 20.00 |

the present observation may be accounted for by the presence of small amount of montmorillonite as an organic complex of montmorillonite in the soil clay.

**Acknowledgements**

Our grateful thanks are due to Dr. K.R. Chakraborty, General Manager, Planning and Development Division, for evincing keen interest in the subject, to Dr. B. K. Banerjee, Additional Superintendent, Physical Research Wing, for giving valuable suggestions and constant encouragement during the progress of work. Thanks are due to Drs. S. K. Ghosh and H. Roy for their assistance in x-ray and D.T.A. studies respectively.

REFERENCES

1. Venkataraman, K. V., Tejwani, K. G., *J. Ind. Soc. Soil Sci.*, **10** (1962), 187.
2. Nagelschmidt, G., Desai, A. D. and Muir, A., *J. Agric. Sci.*, **30** (1940), 639.
3. Kanwar, J. S., *J. Ind. Soc. Soil Sci.*, **7** (1959), 249.
4. Mitra, R. P., *Bull. Indian Soc. Soil Sci.*, **4** (1942), 44.
5. Mukherjee, J. N., Mitra, R. P. and Mitra, D. K., *J. Phys. Chem.*, **47** (1943), 543.
6. Piper, C. S., *Soil and Plant Analysis* (University of Adelaide, Adelaide, Australia), 1963.
7. Jefferies, C. D., *Proc. Soil Sci. Soc. Amer.*, **11** (1947), 211.
8. Hanawalt, J. D., Rinn, H. W. and Frovel, L. K., *Indus. Engng. Chem. (Anal. Ed.)* **10** (1938), 457.
9. Roychaudhury, S. P., Agarwal, R. R., Dutta Biswas, N. R., Gupta, S. P. & Thomas, P. K., *Soils of India* (Indian Council of Agri. Research, New Delhi), 1963.
10. Grim, R. E., *Clay Mineralogy* (McGraw-Hill Book Co. Inc., New York), 1953.
11. Bradley, W. F., *J. Amer. Chem. Soc.*, **67** (1945), 975.
12. Hendricks, S. B., *J. Phys. Chem.*, **45** (1941), 65.
13. MacEwan, D. M. C., *Trans. Farad. Soc.*, **44** (1948), 349.

# A Servo-Type Magnetic Balance for Routine Thermomagnetic Analysis

By

P. C. Banerjie, S. N. Pandey*, L. M. Mazumdar
and P. K. Ghosh,

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

A servo-type thermomagnetic balance, designed in this laboratory, for routine analysis of multicomponent ferromagnetic systems is described. The details of construction and circuit configuration are given. The balance chamber can be evacuated or filled with any desired gas, and the temperature of the non-inductive furnace can be raised upto 1000°C.

**Introduction**

Servo-type magnetic balances or micro-balances have been constructed by many workers[1–5]. The designs differ according to the particular needs to be served, and perhaps more according to the availability of materials of construction. This paper describes such a balance designed to carry out routine thermomagnetic analysis of multicomponent ferromagnetic samples encountered in the industry.

The usual forms of the balance position sensor are: (i) a pair of balanced photocells on which a beam of light reflected from a mirror attached to the balance arm falls; (ii) a differential transformer, whose output depends on the position of a ferromagnetic core suspended from the balance arm; (iii) a capacitative position transducer, and (v) a variable permeability position transducer.

Each of the above methods has its own advantages and disadvantages. The photocells method suffers from the usual difficulties associated with amplifying DC

Present Address: Howard University, U.S.A.

signals from high impedance sources. The use of a ferromagnetic core in the differential transformer is objectionable for magnetic balances. The same objection holds for the variable permeability transducer also. Capacitative transducers, unless differentially connected suffer from large drift and they are sensitive to moisture. The present balance employs a very simple electro-magnetic transducer in the form of a pick-up coil, which eliminates the above objections.

**Description of the Balance**

Basically, the present balance is of Faraday torsion type, in which the magnetic field is applied vertically, and the field gradient is horizontal, so that the torque due to the magnetic pull on the sample at one end of the horizontal balance arm acts in the horizontal plane. The resulting deflection produces an error signal, which is finally converted into a negative feedback balancing torque, that gives a measure of the magnetic pull. The balancing torque is generated by passing an electric current through a coil mounted on the other end of the balance beam, and placed inside the field produced by a pair of permanent magnets. The sample is placed inside a non-inductive electric furnace, the temperature and the balancing torque of which, are simultaneoulsy recorded on a double-channel recorder, and as the successive Curie-points are crossed on raising the temperature, the sharp falls in the magnetic moment are noted; the corresponding temperatures serve to identify the components.

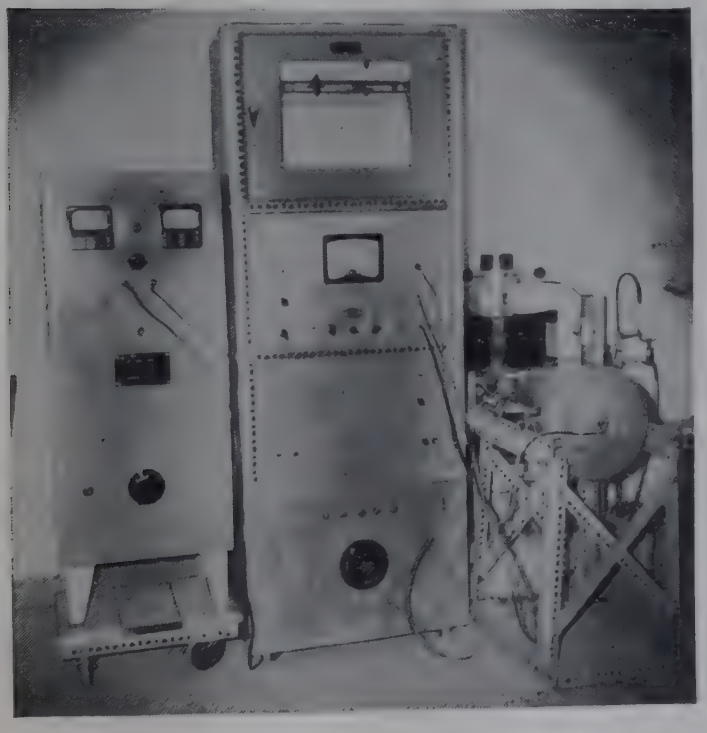


Fig. 1—Overall view of the instrument.

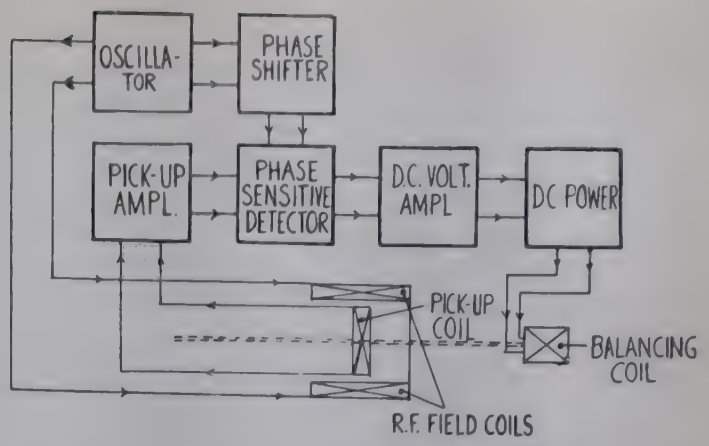



Fig. 2—Block diagram of the electronic circuit.

The instrument (Fig.1) is described in four sections, viz. (i) the circuit, (ii) the mechanical construction of the balance, (iii) the non-inductive furnace and (iv) the electromagnet.

*Circuit:* The block diagram (Fig.2) explains the action of the circuit. The oscillator is a Colpitts circuit, operating at about 500 kHz. The inductance in the tank circuit is in the form of two identical coils connected in series and housed in the balance chamber. These coils are placed on either side of the pick-up coil mounted on the balance-beam, so that the plane of the pick-up coil is parallel to r.f. field set up tetween the pair of oscillator coils. In the undeflected position of the beam, the pick-up amplitude is minimum and is in phase with the r.f. field. When the beam is deflected, the pick-up increases in amplitude and shifts in phase by $\pm$ 90°, the sign depending on the sense of the deflection.

The pick-up signal is amplified by a single stage tuned plate amplifier and the transformer-coupled output is fed to a lock-in phase sensitive detector. An ordinary interstage-coupling transformer, as used in the i.f. stages of domestic wireless receivers, is employed after replacing its internally fitted condenser with another to match the operating frequency.

The reference voltage is supplied to the lock-in phase sensitive detector from the cathode of the oscillator valve, through a phase shifter, and a buffer amplifier stage (Fig.3). The transformer used here is also similar to the one mentioned above. The reference signal here is fed at the centre of two resistances connected across the transformer winding.

The D.C. output from the phase sensitive detector is amplified by a two-stage direct coupled amplifier, whose second stage is a cathode follower with its inherently large negative feed-back to ensure stability and adequate isolation.

The final power stage is designed as a differential amplifier circuit, utilizing a high output twin triode. The advantages of this form are: (i) ability to operate in the linear part of the valve characteristic, and (ii) two-sided output, so that the response covers the diamagnetic range also. In some designs[5], the output valve is operated at or near cut-off. This leads to non-linearity of response.

The balancing coil is connected across the cathodes of the differential amplifer, with one variable resistance in series and one in parallel with it. A milliameter

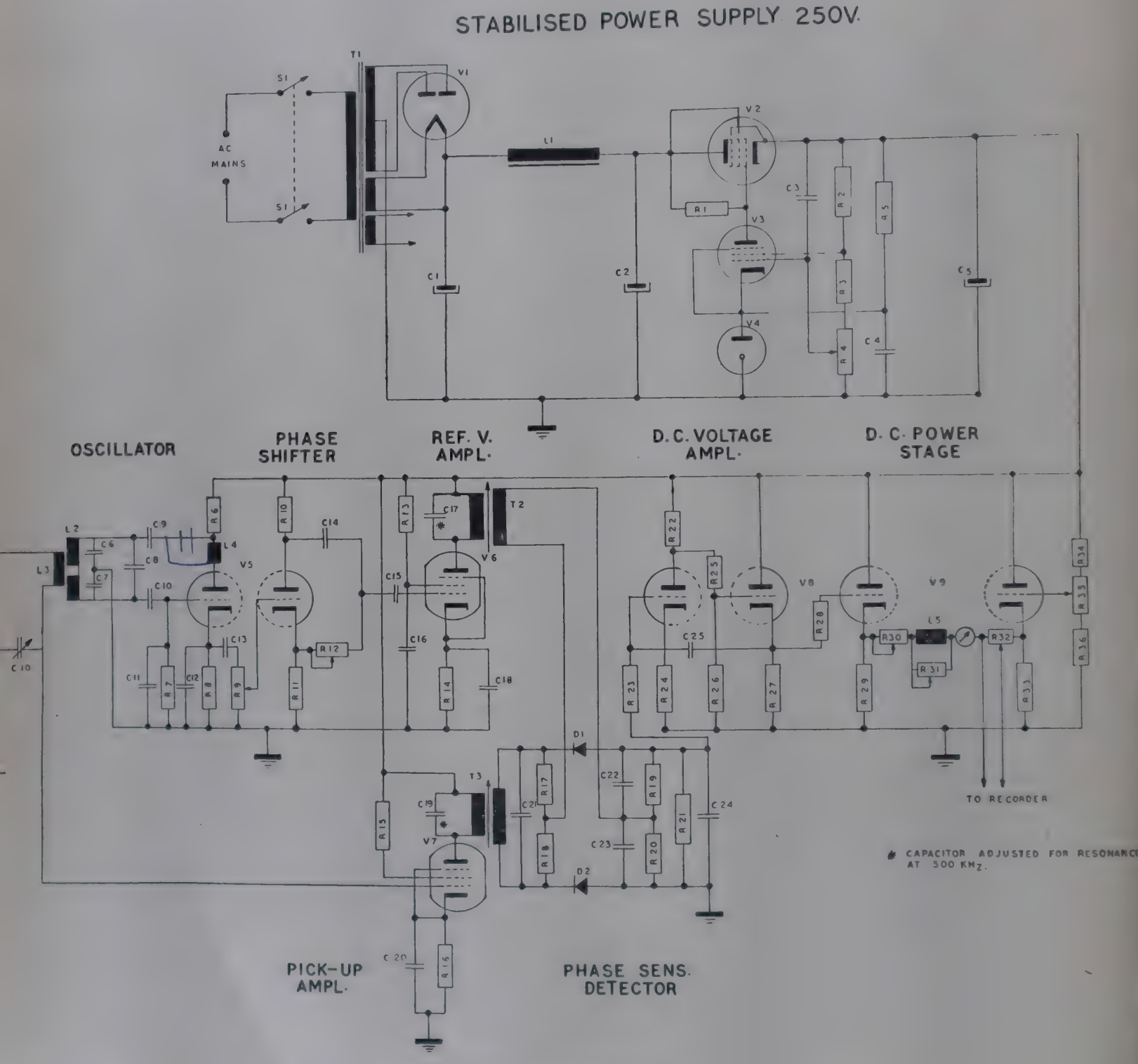



Fig. 3—The complete circuit.

shows the total current passing across the output stage. By putting a low value of the shunt, a small fraction of the total current can be made to pass through the balancing coil, while studying weakly magnetic substances. The accuracy of the measurement does not suffer because the meter shows the total current, which may be kept as many times larger than the actual balancing current, as desired. The series resistance controls the overall sensitivity of the output stage.

A double-channel potentiometer† recorder is employed for recording the output in one channel and the furnace temperature in the other. An adjustable potential divider circuit is used to control the recorder sensitivity (Fig.4). A floating e.m.f. provided by a cell, after being dropped across another potential divider, is used for zero shift of the torque measuring channel of the recorder. A commutator switch controls the sense of the shift. The main purpose of providing the zero shift is to enable one to study under large amplifica ion any selected portion of the thermo magnetic curve, to observe weak magnetic transitions in presence of a strongly magnetic phase as in the case of the Curie-point transitions of iron carbides present in steel.

*Mechanical Construction:* The balance comprises a horizontal silica beam kept under taut suspension from two 32 s.w.g. phosphor-bronze wires from above and below. The end of the beam that goes inside the furnace is shaped into a receptacle for holding rigidly a silica sample container. The other end carries the balancing coil, mentioned earlier, and also a damping vane that dips into an oil dash-pot. The pick-up coil is mounted at the point of suspension, so that it undergoes only an angular displacement. The lead wires of the pick-up coil are made of very thin enamelled copper wire (48 s.w.g.) so that they do not exert any appreciable restraint on the movement of the beam.

The phosphor-bronze suspension wires also serve as the electrical leads for the balancing coil. The retractable top support is used to adjust the tension. The lower suspension wire is attached to a spring, which, in turn, is fixed to a rotating spindle. Its position can be controlled by a small reversible D.C. motor, linked through a three-stage worm reducing gear train. The ultimate reduction ratio is about 1:14000, and the fastest angular speed at the spindle is about 1/3 r.p.m. This movement is used for the initial setting of the orientation of the beam. The motor is energized from the control console, by a 6 volts transformer through

† Honeywell Brown Electronik potentiometer

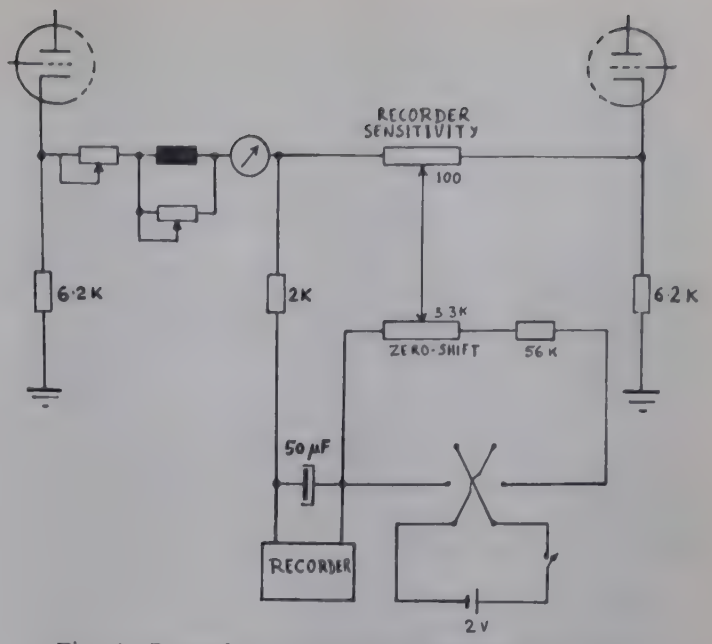



Fig. 4—Recorder zero-shift and sensitivity controls.

a silicon bridge rectifier, a reversing switch and a rheostat for speed control.

The field coils i.e., the r.f. coils of the oscillator tank circuit are wound with 50 turns each of 32 s.w.g. enamelled copper wire, on two rectangular (4 cm. $\times$ 3m.) perspex formers, which fit into specially made grooves on the main framework supporting the suspension system. The positions of the field coils can be adjusted both vertically and horizontally for optimum setting, by means of screws.

The framework supporting the main suspension system is attached to an aluminium disc of about 24 cm. diameter, Another disc of similar dimensions supports the oil-damping pot and the pair of permanent magnets used for the electromagnetic balancing device. The position of the magnet pair can be adjusted so that the balancing coil is symmetrical with respect to them. Four stout aluminium rods keep the two aluminium discs rigidly connected to each other, at a precisely fixed distance.

All the electrical leads come out of a hole made in the rear disc and are connected to the terminals of a multicontact plug.

The whole assembly is put inside an austenitic stainless steel chamber made from a section of 25.5 cm. diam. pipe. The balance assembly is mounted on a slide provided with a stop, so that it can be easily slided in or out of the housing (Fig.5) for maintenance or adjustments. A stainless steel lid is used to close the housing. The coupling flange on the housing carries

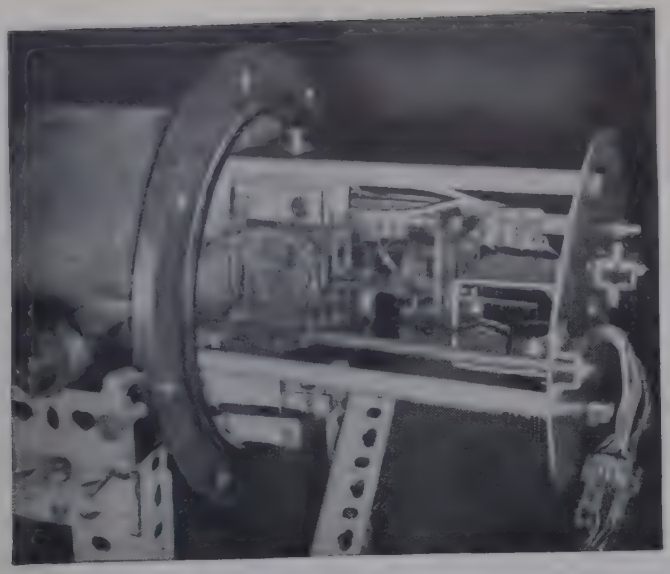


Fig. 5—The balance assembly drawn out from the chamber.

a neoprene 'O'-ring and the chamber, when closed, can be evacuated or filled with any desired gas through ports provided for this purpose. The electrical leads come out through a multicontact plug fitted on the lid that matches the one mentioned before.

For loading the sample, the whole balance housing is rolled out on four wheels moving over a pair of rails, so that the balance beam is completely withdrawn from the furnace (Fig.6).

*The Non-Inductive Furnace* (Fig.7): The furnace tube is about 28 cm. long, 17mm. in diameter, and made of vitreous silica. At one end a thermocouple-well, made of thin silica tube is provided, the other end being attached to a vacuum-proof coupling for connecting it to the balance chamber. 32 s.w.g. nichrome wire is wound over the furnace tube in a non-inductive manner, the end loop of the winding being looped over a small knob made at the thermocouple end of the tube. Thin asbestos rope is then tightly wound over the winding to prevent displacement and consequent short-circuiting on heating. A thin layer of mica is next used, over which a layer of high temperature cement is applied. The whole thing is placed inside a double-walled copper jacket, with cooling water circulating in-between. Suitably placed baffles inside the

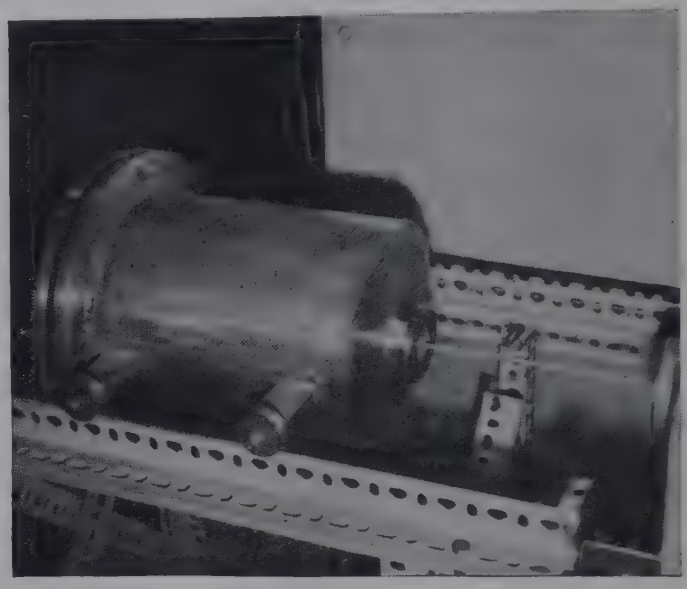


Fig. 6—The balance ready for sample loading.

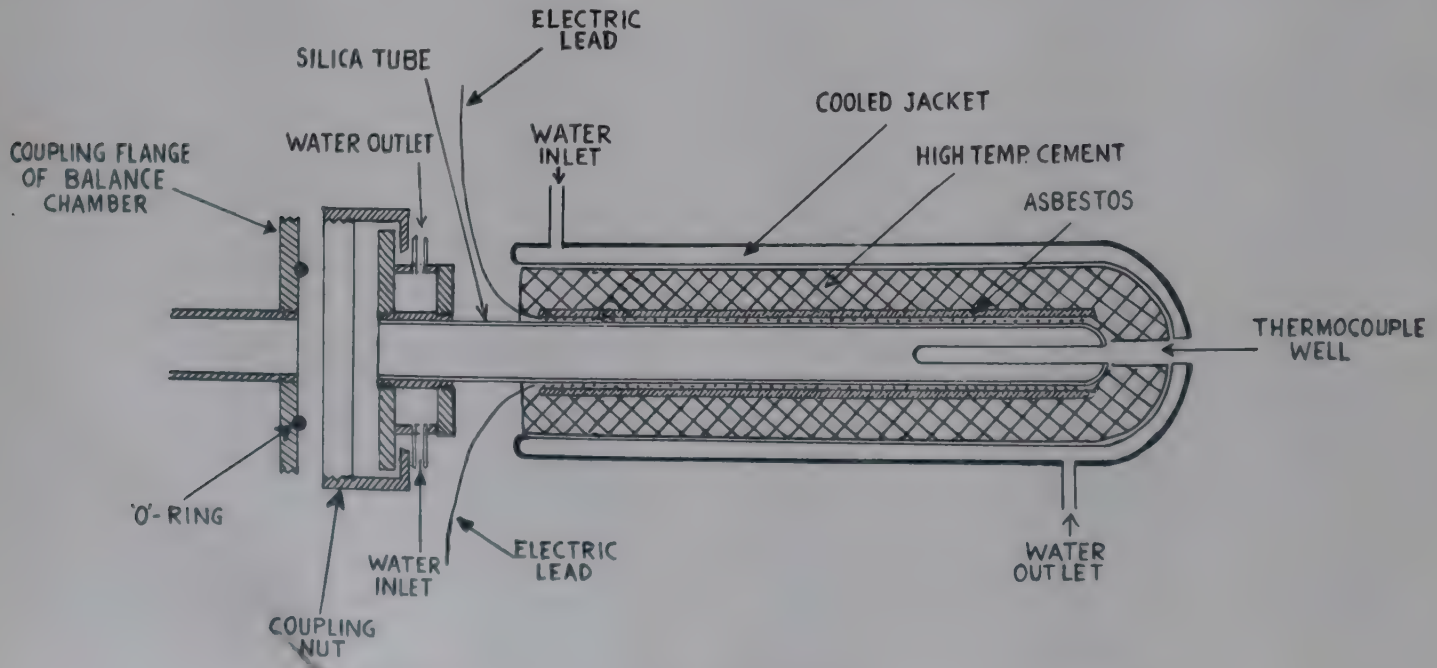



Fig. 7—Sectional view of the furnace and the vacuum-proof coupling.

annular space guide the water along a helical path, thus ensuring uniform cooling all over. A specially protected opening is made in the copper jacket to correspond with the thermocouple well, so that a thermocouple can be easily inserted or taken out without disturbing anything.

The device for coupling the furnace to the balance chamber consists of a water cooled stainless steel flange, carrying a large locking nut that engages with a corresponding threaded flange on the balance housing; a neoprene 'O'-ring is again used for vacuum-proof coupling. The assembly is fixed to the silica furnace tube by "Araldite" cement; the circulating water always keeps the temperature of the joint below the softening point of "Araldite".

The furnace winding is energized through a continuously variable autotransformer housed in the control

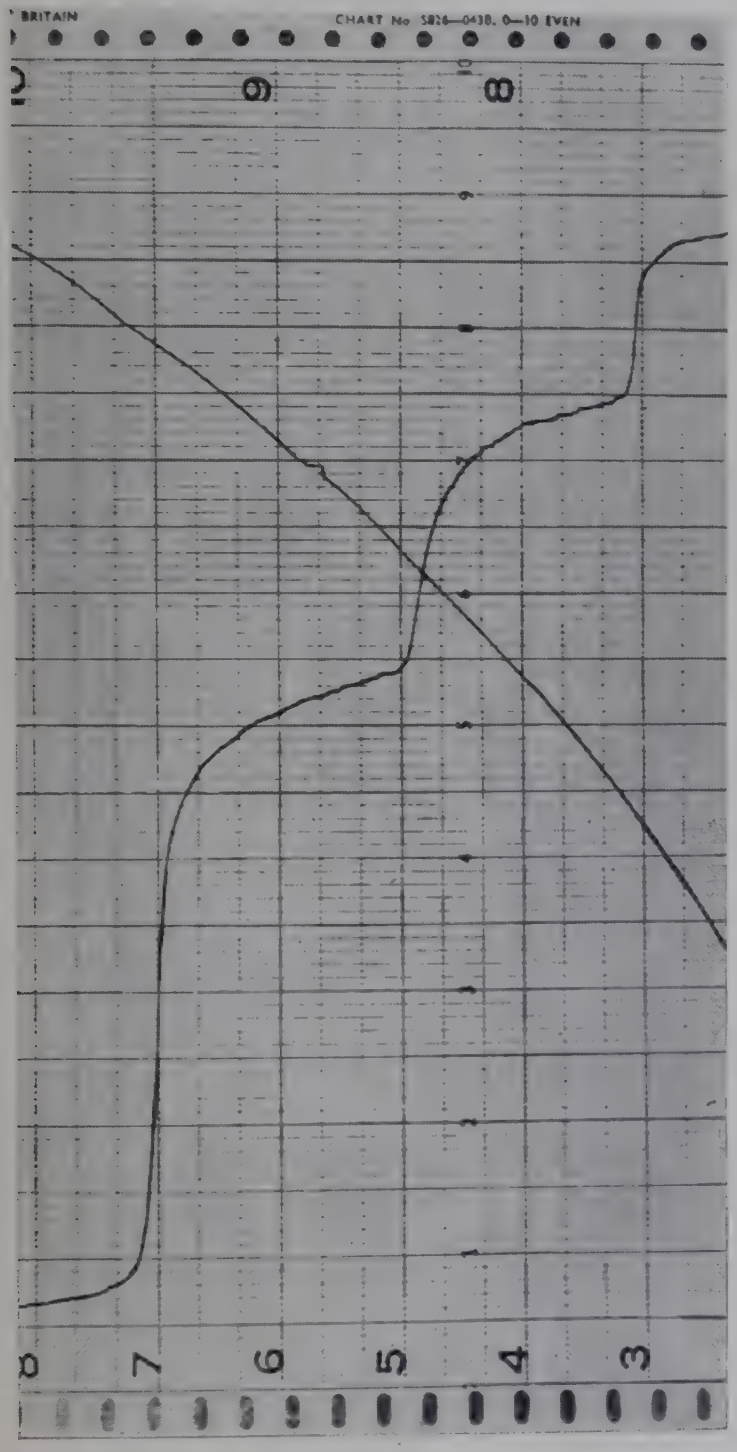


Fig. 8a

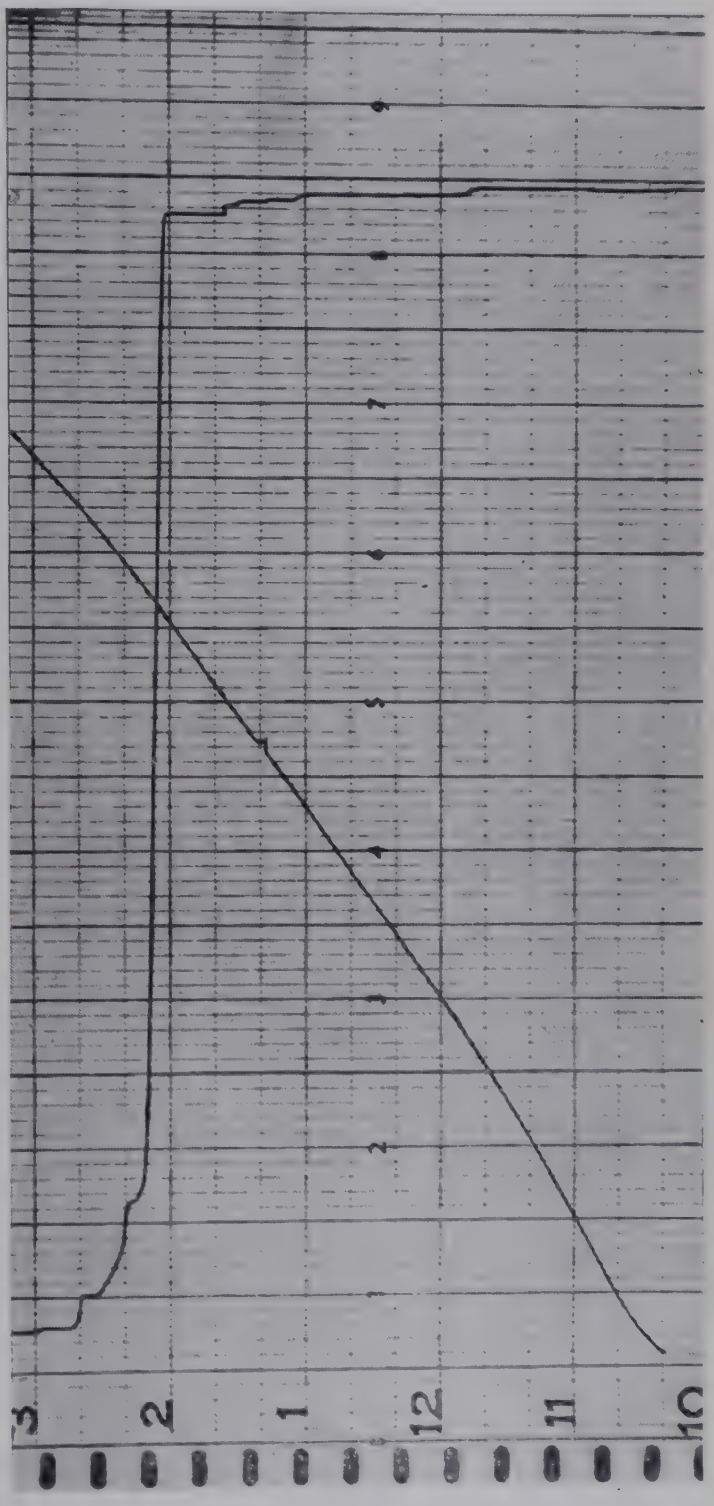


Fig. 8b

Fig. 8—Typical recordings.

console (see Fig.1). The furnace temperature reaches 1000°C at an energizing voltage of 130 volts. The rate of heating can be controlled by adjusting the energizing voltage, the fastest rate attainable being about 100°C/min. Such a fast rate is of course never employed, for the lag in the thermocouple circuit makes it impossible to record the temperature accurately. The rate usually employed is 20°C/min. The temperature of the furnace is measured by a chromel-alumel thermocouple whose output is fed to the recorder through a calibrated voltage divider.

*Electromagnet:* A UNICO†† electromagnet has been used, mounted in a vertical position with a sturdy stand, so that field direction is vertical. A specially shaped pole shoe, after the design of Sucksmith[6], introduces a horizontal field gradient perpendicular to the balance beam. The furnace assembly is held rigidly between the pole pieces in a clamp. The field strength attained is about 3000 Oersteds at a magnetizing current of 4 amps. and the gradient at this field strength is about 10 Oersteds/cm. at the centre.

The magnetizing current is supplied by a UNICO D.C. power suply, which itself is connected to the mains through a voltage stabilizing transformer.

Fig. 8a is a reproduction of the recorder chart showing the Curie-point transitions in a sample containing metallic nickel, magnetite, and metallic iron. It may be seen that the different transitions are very clearly marked. Fig. 8b shows the curve obtained with an ammonia synthesis catalyst.

The balance can also be used to measure the susceptibility of paramagnetic substances by first calibrating it against suitable standards and then reading the balancing current required for the unknown sample, after making necessary correction for the empty sample carrier, beam, etc. Such measurements are possible, because the sensitivity of the balance can be controlled over a very wide range by adjusting the amount of feed back, in the form of the shunt for the balance coil.

The instrument is at present in daily use to study such varied samples as metal specimens, catalysts, rock samples, chemical complexes, etc.

†† Universal Scientific Co; type NP-53

**Acknowledgement**

The authors are thankful to Dr. B. K. Banerjee, Additional Superintendent (PRW), for encouragement and to Dr. K. R. Chakravorty, General Manager, for his keen interest in the work.

REFERENCES

1. Hirome, T. and Maeda, S., *Rev. Sc. Intr.*, **25** (1964), 516.
2. Cochran, C. N., *ibid*, **29** (1958), 1135.
3. Hidgcock, F. T. and Muir, W. B., *ibid*, **31** (1960), 390.
4. Lincoln, K. A., *ibid*, **31** (1960), 537.
5. Butera, R. A., Craig, R. S. and Cherry, L. V., *ibid*, **32** (1961), 708.
6. Sucksmith, W., *Proc. Roy. Soc.*, **A170** (1939), 551.

# Investigation into the Use of Algae for Removing Ammonium Nitrogen from Nitrogenous Industrial Wastes

## Part 2—Semi-Continuous Laboratory Studies

By

G. S. Bhattacharyya, G. S. Roy and B. K. Dutta,

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

In this part, studies were made with semi-continuous cultures using the synthetic nitrogenous waste water and the same strain of *Chlorella pyrenoidosa* as in the batch experiments. Algal growth rate and rate of ammonium nitrogen utilization increased about two-fold over the same in the batch studies. Steady state conditions as regards algal concentration, ammonium nitrogen, phosphate phosphorus, alkalinity, pH and optical density were reached after operating the semi-continuous cultures for a number of days depending upon the detention period.

The first paper of the series[1] dealt with the growth, ammonium nitrogen metabolism and nutritional requirements of batch culture of algae in synthetic nitrogenous waste. Since a batch culture suffers from some limitations owing to the constantly changing nutritional environments to which algal cells remain exposed and which are supposed to have adverse effects on algal growth and nutrient uptake, it was felt that rates of growth and nutrient utilization by algae would show further improvement if studies were made with continuous or semi-continuous cultures wherein environmental fluctuations would be minimized once the steady state conditions were achieved after running the culture for some days.

### Experimental

The experimental growth studies were conducted in a laboratory model of multi-unit algal growth apparatus which consisted of 4 clear glass bottles in series each having 3 l. capacity. Every bottle was filled with 2 l. of culture thus giving a total cultue volume of 8 l. in the growth apparatus.

This apparatus was placed on a specially-built platform outside the eastern windows of the laboratory where the cultures remained exposed to outside hot and dry (March-May) weather with the exception of a few days of overcast sky. Incident light intensities on the culture surfaces varied widely and ranged from 300 to 11,000 foot candles (ft.c) with a day-time average of approximately 4450 ft.c. The culture temperature cycle varied from 28°C at 7 a.m. to 40°C at 2 p.m. but sometime during the summer (April-May), the cultures attained a temperature as high as 47°C. This resulted into inhibition of algal growth, necessitating some control over the culture temperature. Therefore, cultures were maintained at 40°C or below by spraying cold tap water on the outside walls of the culture bottles.

Culture mixing was done by bubbling diluted carbon dioxide through the culture at a rate of 170-200 ml./min. To keep the algae in suspension and prevent their settling at the bottom and adhering to the sides, a thorough shaking was given to each culture bottle occasionally.

The operation of the growth apparatus was semi-continuous. Every morning a certain fraction of the culture was removed from each bottle and transferred to the next one, the amount depending upon the detention period desired. The culture removed from the last bottle of the series comprised the effluent of the system. The influent to the system, consisting of the same amount of synthetic nitrogenous waste as was discharged from the last bottle, was introduced in the first bottle of the growth apparatus and had the following characteristics: pH 7; total alkalinity as $CaCO_3$ 80 mg./l., total dissolved solids 1460 mg/l., ammonium nitrogen 280 mg/l. and oxidized nitrogen 8 mg./1.

The test organism employed was the same strain of *Chlorella pyrenoidosa* used in the previous study[1]. Each test was begun by filling the culture bottles to the 2 l. mark by a previously prepared culture grown on the same synthetic nitrogenous waste. This ensured that each culture started with the same composition as the others. The feed cycle was initiated immediately afterwards. With this procedure a minimum time-period was required to bring the system to a steady-state condition. The growth apparatus was operated at two different detention periods i.e. 8 days (Run-I), and 5 days (Run-II).

The feed medium employed in this investigation was the same synthetic nitrogenous waste water as was used previously[1]. It was prepared by dissolving 1.22 g. fertilizer grade ammonium sulphate per l. of tap water. Alakalinity, phosphate and trace elements, were not added to this stock of nitrogenous waste water. The alkalinity was added as calcium carbonate powder with the daily feed. The portion of daily feed containing the calcium carbonate suspension was carbonated with raw carbon dioxide (80 per cent $CO_2$) before introducing the same to the growth apparatus. This helped to keep the major part of calcium carbonate in solution and inhibited the precipitation of calcium carbonate in the growth units. Phosphate was added as potassium phosphate (dibasic) solution to each of the units separately though initially it was added along with the daily feed. The practice of phosphate addition with the daily feed created phosphate precipitation problems and had to be discontinued. Trace elements other than iron were added to each growth unit from a stock trace element solution prepared by dissolving 440 mg. $ZnSO_4$. $7H_2O$, 80 mg.$CuSO_4.H_2O$, 100 mg. $CO(NO_3)_2$. $6H_2O$, 40 mg. ammonium molybdate, 20 mg. $MnSO_4$. $H_2O$ and 1130 mg $H_3BO_3$ in 100 ml. distilled water. Iron was fed to each unit as ferrous sulphate solution. Carbon was supplied to the growth apparatus as 8 per cent carbon dioxide gas with air as a diluent at a rate of 170-200 ml/min of the gas for 8 hours i.e. from 8 a.m. to 4 p.m. every day.

Effluent discharge was done daily at about 7-30 a.m. and an equal amount of synthetic waste was fed immediately. The discharge from the last growth unit was analysed daily for pH, total alkalinity, dissolved solids, algal concentration, optical density, ammonium nitrogen, oxidized nitrogen and phosphate. Also, the cultures from the first, second and third growth units were analysed daily only for pH and optical density, because other analyses would have resulted in some loss of culture volume necessitating unnecessary volume corrections. The portions of culture drawn from the first to third growth units for above-mentioned determinations were recycled to the respective units.

**Results and Discussion**

The data of the Experimental Runs I and II of the growth apparatus with detention periods of 8 and 5 days respectively are presented below (Tables 1-4).

*Results of Experimental Run I:* The growth apparatus was operated at 8 days' detention period for 22 days. The daily feed and discharge were 1l. each. The system attained almost a semi-equilibrium or semi-steady state condition as regards ammonium nitrogen, phosphate phosphorus and alkalinity on the 13th day of the experiment (Table 1). Ammonium nitrogen of the final effluent at this stage ranged from 28 to 33 mg./l., phosphate phosphorus from 4.8 to 8.3 mg./1, total alkalinity from 44 to 84 mg./l., and algal concentration from 2440 to 2670 mg./1. (Table 1).

It may be seen that after the system had attained the steady-state condition, algae-to-nitrogen ratio* ranged from 9.9 to 10.7, average being 10.3 This average value seems to be somewhat on the higher side as algal suspended solid included a small amount of calcium carbonate that invariably got precipitated in the cultures during high photosynthetic activity as would be evident from the higher values of alkalinity to nitrogen ratio**. This ratio ranged from 4.6 to 5.4, average being 5.0, whereas the theroretical value should be about 3.6.

The ratios of algae-to-phosphorus† and nitrogen-to-phosphorus†† averaged 53 and 5.1 respectively. These

* mg. of algae produced per mg. of nitrogen removed.

** mg. of alkalinity (expressed as $CaCO_3$) destruction associated with each mg. of ammonium nitrogen metabolized.

† mg. algae produced per mg. phosphorus depleted.

†† mg. nitrogen removed per mg. phosphorus depleted.

TABLE 1—Operating Characteristics of the Multi-Unit Algal Growth Apparatus at 8 Days' Detention Time

| Days After Start of Experiment | Influent Flow, l./day | Effluent Flow, l./day | Influent Analyses, mg./l. | | | Effluent Analyses, mg./l. | | | Reduction of nutrients, mg./l. | | | Algae formation as Suspended Solid, mg./l. dry weight | Ratios of | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ammonium Nitrogen ($NH_4$-N) | Phosphate Phosphorus ($PO_4$-P) | Total Alkalinity as $CaCO_3$ | Ammonium Nitrogen ($NH_4$-N) | Phosphate Phosphorus ($PO_4$-P) | Total Alkalinity as $CaCO_3$ | Ammonium Nitrogen ($NH_4$-N) | Phosphate Phosphorus ($PO_4$P) | Total Alkalinity as $CaCO_3$ | | Algae formation to Ammonium Nitrogen Removal | Algae formation to Phosphate Phosphorus Depletion | Alkalinity Destruction to $NH_4$-N Removal | Nitrogen Removal to Phosphate Phosphorus Depletion |
| 0 | 1.0 | 1.0 | 280 | 65.5 | 576 | 169 | 10.6 | 78 | 111 | 55 | 498 | 1833 | 16.5 | 33 | 4.5 | 2.0 |
| 1 | 1.0 | 1.0 | 280 | — | 696 | 147 | 13.0 | 60 | 133 | — | 636 | 1975 | 14.8 | — | 4.8 | — |
| 2 | ,, | ,, | ,, | 46 | 542 | 120 | 5.5 | 46 | 160 | 40.5 | 496 | 2350 | 14.7 | 59 | 3.1 | 3.9 |
| 3 | ,, | ,, | ,, | 27.3 | 1061 | 104 | 8.3 | 48 | 176 | 19.0 | 1013 | 2450 | 13.9 | 129 | 5.8 | 4.0 |
| 4 | ,, | ,, | ,, | 33 | 1071 | 97 | — | 57 | 183 | — | 1014 | 2190 | 12 | — | 5.5 | — |
| 5 | ,, | ,, | ,, | 39 | 1092 | 98 | 4.8 | 38 | 182 | 34 | 1051 | 2272 | 12.5 | 66 | 5.8 | 5.4 |
| 6 | ,, | ,, | ,, | 27.3 | 1345 | 95 | 4.7 | 28 | 185 | 22.6 | 1317 | 2220 | 12 | 97 | 7.1 | 8.2 |
| 7 | ,, | ,, | ,, | 87 | 1663 | 80 | 0.1 | 40 | 200 | 87 | 1623 | 2100 | 10.5 | 24 | 8.1 | 2.3 |
| 8 | ,, | ,, | ,, | 95.3 | 1708 | 63 | 0.87 | 52 | 217 | 94.4 | 1656 | 2100 | 9.7 | 22.3 | 7.6 | 2.3 |
| 9 | ,, | ,, | ,, | 65.6 | 1622 | 55 | 3.9 | 72 | 225 | 61.7 | 1550 | 2110 | 9.8 | 34 | 6.9 | 3.6 |
| 10 | ,, | ,, | ,, | 66 | 1622 | 42 | 7.1 | 56 | 238 | 59 | 1566 | 2275 | 9.6 | 38.6 | 6.6 | 4.0 |
| 11 | ,, | ,, | ,, | 66 | 1622 | 40 | 8.3 | 64 | 240 | 58 | 1558 | 2416 | 10.0 | 41.7 | 6.5 | 4.1 |
| 12 | ,, | ,, | ,, | 56 | 1302 | 33 | 8.0 | 64 | 247 | 48 | 1238 | 2440 | 9.9 | 51 | 5.0 | 5.1 |
| 13 | ,, | ,, | ,, | 56 | 1362 | 29 | 8.3 | 56 | 251 | 47.7 | 1305 | 2485 | 9.9 | 51.8 | 5.2 | 5.2 |
| 14 | ,, | ,, | ,, | 56 | 1404 | 33 | 5.8 | 56 | 247 | 50.2 | 1348 | 2500 | 10.1 | 50 | 5.4 | 4.9 |
| 15 | ,, | ,, | ,, | 56 | 1404 | 28 | 4.8 | 44 | 252 | 51.2 | 1360 | 2540 | 10.0 | 50 | 5.2 | 5.0 |
| 16 | ,, | ,, | ,, | 56 | 1382 | 32 | 6.2 | 84 | 248 | 49.8 | 1298 | 2644 | 10.7 | 53 | 5.2 | 5.0 |
| 17 | ,, | ,, | ,, | ,, | 1282 | 32 | 6.2 | 76 | 248 | 49.8 | 1206 | 2570 | 10.4 | 51.4 | 5.1 | 5.0 |
| 18 | ,, | ,, | ,, | ,, | 1282 | 29 | 7.3 | 48 | 251 | 48.7 | 1234 | 2670 | 10.6 | 54.5 | 4.9 | 5.1 |
| 19 | ,, | ,, | ,, | ,, | 1249 | 28 | 8.0 | 84 | 252 | 48.2 | 1168 | 2656 | 10.5 | 55.3 | 4.6 | 5.3 |
| 20 | ,, | ,, | ,, | ,, | 1282 | 31 | 4.8 | 68 | 249 | 51.2 | 1214 | 2670 | 10.7 | 52.4 | 5.0 | 5.0 |
| 21 | ,, | ,, | ,, | ,, | 1282 | 30 | 7.6 | 84 | 250 | 48.4 | 1198 | 2644 | 10.6 | 55 | 4.8 | 5.2 |
| 22 | ,, | ,, | ,, | ,, | 1273 | 30 | 8.2 | 70 | 250 | 47.8 | 1203 | 2570 | 10.3 | 54.0 | 4.8 | 5.2 |

—No data

TABLE 2—OPERATING CHARACTERISTICS OF THE MULTI-UNIT ALGAL GROWTH APPARATUS AT 5 DAYS' DETENTION TIME

| Days After Start of Experiment | Influent Flow, l./day | Effluent Flow, l./day | Influent Analyses, mg./l. | | | Effluent Analyses, mg./l. | | | Reduction of nutrients, mg./l. | | | Algae formation as Suspended Solid, mg./l. dry weight | Ratios of | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ammonium Nitrogen ($NH_4$-N) | Phosphate Phosphorus ($PO_4$-P) | Total Alkalinity as $CaCO_3$ | Ammonium Nitrogen ($NH_4$-N) | Phosphate Phosphorus ($PO_4$-P) | Total Alkalinity as $CaCO_3$ | Ammonium Nitrogen ($NH_4$-N) | Phosphate Phosphorus ($PO_4P$) | Total Alkalinity as $CaCO_3$ | | Algae formation to Ammonium Nitrogen Removal | Algae formation to Phosphate Phosphorus Depletion | Alkalinity Destruction to $NH_4$-N Removal | Nitrogen Removal to Phosphate Phosphorus Depletion |
| 0 | 1.6 | 1.6 | 280 | 26 | 796 | 120 | 3 | 68 | 160 | 23 | 728 | 1672 | 10.4 | 73 | 4.5 | 7.0 |
| 1 | 1.6 | 1.6 | ,, | 29 | 802 | 85 | 5 | 68 | 195 | 24 | 734 | 1490 | 7.6 | 62 | 3.8 | 8.1 |
| 2 | ,, | ,, | ,, | 29 | 802 | 43 | 4 | 72 | 237 | 25 | 730 | 1845 | 8.0 | 74 | 3.0 | 9.5 |
| 3 | ,, | ,, | ,, | 29 | 802 | 20 | 2 | 66 | 260 | 27 | 736 | 2266 | 8.7 | 84 | 2.8 | 9.6 |
| 4 | ,, | ,, | ,, | 37 | 817 | 74 | — | 59 | 206 | — | 758 | 2035 | 9.9 | — | 3.7 | — |
| 5 | ,, | ,, | ,, | 37 | 817 | 98 | 2.5 | 124 | 182 | 34.5 | 693 | 1746 | 9.6 | 51 | 3.8 | 5.3 |
| 6 | ,, | ,, | ,, | 31 | 806 | 120 | 5.0 | 138 | 160 | 26 | 668 | 1550 | 9.7 | 60 | 4.3 | 6.1 |
| 7 | ,, | ,, | ,, | 31 | 806 | 115 | 5 | 166 | 165 | 26 | 640 | 1460 | 8.8 | 56 | 4.0 | 6.3 |
| 8 | 1.6 | 1.6 | 280 | 22.5 | 628 | 122 | 3.5 | 142 | 158 | 19 | 486 | 1325 | 8.4 | 69.7 | 3.1 | 8.3 |
| 9 | ,, | ,, | ,, | ,, | 628 | 128 | 5.0 | 74 | 152 | 17.5 | 554 | 1205 | 8.0 | 69 | 3.6 | 8.7 |
| 10 | ,, | ,, | ,, | ,, | 628 | 129 | 5.5 | 75 | 151 | 17.0 | 553 | 1272 | 8.4 | 74.8 | 3.7 | 9.0 |
| 11 | ,, | ,, | ,, | 22.5 | 603 | 128 | 5.5 | 47 | 152 | 17 | 556 | 1238 | 8.1 | 73 | 3.6 | 9.0 |
| 12 | ,, | ,, | ,, | 22.5 | 603 | 128 | 5.5 | 50 | 152 | 17 | 553 | 1240 | 8.2 | 66 | 3.6 | 9.0 |
| 13 | ,, | ,, | ,, | ,, | 603 | 137 | 6.5 | 88 | 143 | 16 | 515 | 1290 | 9.0 | 81 | 3.6 | 9.0 |
| 14 | ,, | ,, | ,, | ,, | 628 | 139 | 6.0 | 74 | 141 | 16.5 | 554 | 1265 | 9.0 | 77 | 3.9 | 8.5 |
| 15 | ,, | ,, | ,, | ,, | ,, | 139 | 6.0 | 96 | 141 | 16.5 | 532 | 1190 | 8.4 | 70 | 3.7 | 8.5 |
| 16 | ,, | ,, | ,, | ,, | ,, | 136 | 6.0 | 78 | 141 | 17.0 | 550 | 1150 | 8.2 | 70 | 3.9 | 8.5 |
| 17 | ,, | ,, | ,, | ,, | ,, | 138 | 6.5 | 90 | 142 | 16.0 | 538 | 1220 | 8.6 | 76.2 | 3.8 | 8.9 |
| 18 | ,, | ,, | ,, | ,, | ,, | 136 | 5.5 | 106 | 144 | 17.0 | 522 | 1187 | 8.2 | 70 | 3.6 | 8.5 |
| 19 | ,, | ,, | ,, | ,, | ,, | 139 | — | 104 | 141 | — | 524 | 1212 | 9.0 | — | 3.7 | — |
| 20 | ,, | ,, | ,, | ,, | ,, | 134 | 4.0 | 98 | 146 | 18.5 | 530 | 1215 | 8.3 | 66 | 3.6 | 8.0 |
| 21 | ,, | ,, | ,, | ,, | ,, | 130 | 6.0 | 106 | 150 | 16.5 | 522 | 1320 | 9.0 | 80 | 3.5 | 9.1 |
| 22 | ,, | ,, | ,, | ,, | 628 | 132 | 6.0 | 100 | 150 | 16.0 | 524 | 1310 | 8.7 | 82 | 3.5 | 9.4 |

—No data

TABLE 3—AVERAGE RATES OF ALGAL GROWTH AND NUTRIENT UTILIZATION IN SYNTHETIC NITROGENOUS WASTE WATERS USING SEMI-CONTINUOUS CULTURES

| Experimental Run No. | Length of Run days | Detention Period, days | Algae Conc., mg./l. dry weight | | Average rate of Algal Growth mg./l/day | Optical Density (E) | | Rate of Increase in Optical Density day | Ammonium Nitrogen, mg/l. | | Average Rate of $NH_4$-N Utilization, mg./l/day | Phosphate Phosphorus, mg./l. | | Average Rate of Phosphate Phosphorus Removal, mg./l./day | Total Alkalinity, mg./l. of $CaCO_3$ | | Average Rate of Alkalinity Destruction, mg./l/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Influent | Effluent | | Influent | Effluent | | Influent | Effluent | | Influent | Effluent | | Influent | Effluent | |
| I | 22 | 8 | 0.0 | 2580 | 322 | 0.10 | 2.40 | 0.29 | 280 | 30 | 31 | 51 | 7 | 5.5 | 1319 | 69 | 156 |
| II | 22 | 5 | 0.0 | 1220 | 244 | 0.0 | 1.30 | 0.26 | 280 | 134 | 29 | 22.5 | 5.7 | 3.4 | 621 | 85 | 107 |

values were somewhat lower than normal, and indicated that depletion of phosphorus from the culture solutions was generally somewhat more than what can be accounted for by algal uptake alone. Chemical precipitation as insoluble phosphates seemed to play some part in phosphorus depletion in an algal culture even at the pH range of 6.5-7.2, which was maintained in all the cultures.

It is evident from Table 1 that by operating the semi-continuous algal growth apparatus it is possible to reduce the ammonium nitrogen content of a nitrogenous waste water from 280 to 28-33 mg./l. allowing a detention period of 8 days only.

A study of the daily variation in optical densities of the cultures contained in different units of the growth apparatus showed that with increasing detention period the optical density of the cultures increased. The table below gives the optical density range of the various growth units. It shows that the first unit was operated at minimum algal density which resulted in maximum light penetration. The conditions in the last growth unit were quite the reverse i.e. the unit being run at maximum algal density and minimum light penetration. This resulted in the maximum growth rate and ammonium nitrogen utilization in the first growth unit and minimum growth rate and nitrogen utilization in the last unit.

| Growth Unit No. | Detention period in days | Optical density (E) range |
|---|---|---|
| Sc I | 2 | 0.8 —0.9 |
| Sc II | 4 | 1.44—1.6 |
| Sc III | 6 | 2.00—2.12 |
| Sc IV | 8 | 2.2 —2.5 |

The pH fluctuations from unit to unit were found to be negligible and varied within a narrow range of 6.5-7.2; the maximum pH level, however, was maintained at Unit Sc I and minimum at Unit Sc IV.

It may also be noted that there exists some definite relationship between algae formation and nitrogen removal. As algal density increased in the culture, nitrogen level decreased and when the algal population attained an equilibrium value nitrogen level also became steady.

*Results of Experimental Run II:* The operating characteristics of growth apparatus operated at 5 days detention period (Experimental Run II) are given in Table 2. The techniques of operation and start-up

TABLE 4—ANALYSIS OF THE CULTURES CONTAINED IN THE DIFFERENT GROWTH UNITS OF THE MULTI-UNIT ALGAL GROWTH APPARATUS AT THE END OF THE EXPERIMENTAL RUN I

| Growth Unit No. | pH | Total Alkalinity, mg./l. as $CaCO_3$ | Total Dissolved Solid, mg./l. | Algal Concentration as | | Inorganic Nitrogen, mg./l. | | Phosphate Phosphorus, ($PO_4$-P) mg./l. |
|---|---|---|---|---|---|---|---|---|
| | | | | Optical Density (E) | Suspended Solid, mg./l. dry weight | Ammonium Nitrogen ($NH_3$-N) | Oxidized Nitrogen (Oxd. N) | |
| Sc. I | 7.8 | 506 | 1712 | 0.94 | 1193 | 198 | 6 | 3.7 |
| Sc. II | 7.4 | 320 | 1796 | 1.56 | 1634 | 130 | 5 | 4.5 |
| Sc. III | 7.2 | 124 | 1800 | 1.96 | 2200 | 75 | 6 | 4.0 |
| Sc. IV | 7.3 | 56 | 1840 | 2.40 | 2640 | 31 | 6 | 4.7 |

were the same as the previous experiment. Only change in this series was the daily feed and discharge schedules which were 1/5th of the total culture volume i.e. 1600 ml. The weather conditions were more or less the same as before though sometimes solar radiation and day temperature were higher, necessitating frequent cooling of the culture bottles. The Table 2 shows that the system reached a semi-equilibrium condition on and from the 10th day i.e. 9 days after start of the experimental run when ammonium nitrogen in the effluent ranged from 128-139 mg./l., phosphate phosphorus from 4.0-6.5 mg./l. and total alkalinity from 50-106 mg./l. A semi-steady state was also reached as regards algal population which ranged from 1150-1320 mg./l. Algae-to-nitrogen ratio varied from 8.0 to 9.0, average value being 8.6 (Table 2). These values were somewhat lower than those obtained in the run I, probably due to less precipitation of calcium carbonate in this series as would be evident from lower alkalinity destruction to ammonium nitrogen removal ratio which varied between 3.5 and 3.9, average being 3.7.

Algae-to-phosphorus and nitrogen-to-phosphorus ratios were also higher than in the previous experimental run, average values being 73 and 8.8 respectively which indicated that phosphorus depletion by precipitation was also less in this case. This may be attributed to the difference in detention periods in the two experimental runs, the experiment with higher detention period causing more phosphate and calcium carbonate precipitation and *vice versa*. The daily feed of the multi-unit algal growth apparatus, run at a higher detention period, contained more calcium carbonate alkalinity which was difficult to be brought into solution at the existing pH and carbon dioxide concentration. This caused precipitation of some calcium carbonate in the growth units. The higher alkalinity of the cultures of experimental run I was probably responsible for more phosphate precipitation too.

As the culture passed from one bottle to the next, its optical density increased, the cultures in the last unit showing the maximum optical density. But the levels of optical densities maintained by different units of the growth apparatus in experimental run II were lower than those of the run I owing to the lower detention period of the former. The daily pH variations in the different units of the growth apparatus in the experimental run II are almost identical to those of the run I.

Table 3 indicates that the rates of algal growth and nutrient uptake by algae have almost doubled the corresponding values obtained from batch culture studies. The average rates of algal growth and nitrogen removal were 322 and 31 mg./l. day respectively for 8 days' detention period and 244 and 29 mg./l day respectively for 5 days' detention period. The rate of nitrogen utilization by algae is not affected significantly by changing the detention period from 8 to 5 days, though phosphate and alkalinity removals were more with 8 days' detention period.

Table 4 presents the analyses of the different cultures of the growth unit at the end of the experimental run I (with 8 days' detention). It shows that ammonium nitrogen, alkalinity and pH decreased gradually whereas dissolved solids, optical density and algal suspended solids increased gradually as the culture solution passed from one unit to the other. It is also evident that the maximum destruction of alkalinity

and the maximum removal of ammonium nitrogen took place in the first unit of the growth apparatus where conditions were most favourable due to the presence of abundant nutrients, high light penetration and low optical density. The performance and operating condition of the last unit were just the reverse, the unit being run at highest optical density and lowest light penetration. As oxidized nitrogen did not show any significant variations at the inlet and outlet of the growth apparatus, these had not been included in the table.

Though no attempt was made to maintain pure culture conditions during these experiments, microscopic examination revealed that *Chlorella pyrenoidosa* was by far the most predominant algal strain observed in all the four units of the algal growth apparatus throughout the experimental run.

**Summary and Conclusion**

Semi-equilibrium condition was established after continuously running the growth apparatus for a number of days when the effluent showed steady values as regards pH, optical density, ammonium nitrogen, phosphate phosphorus, algal concentration, alkalinity and dissolved solids. The growth units could be run at this equilibrium condition for a indefinite period of time provided there are no major fluctuations in environmental conditions.

After attaining the steady state conditions, the growth unit showed a nitrogen removal rate of 29-31 mg./l./day and 243-322 mg./l./day of algal solid formation. These values are almost double the corresponding values obtained in the earlier batch studies.

The present investigation not only corroborates the findings of the earlier batch study but also made further improvement on the technique of utilizing algae for treating nitrogenous industrial wastes in a continuous process. By adopting the semi-continuous feeding and discharge techniques, it had been possible to reduce the ammonium nitrogen content of the nitrogenous waste water from 280 to 28-33 mg./l. day in eight days only.

The growth rate and rate of nitrogen metabolism by algae are expected to improve still further if experiments are conducted with semi-continuous/continuous cultures at constant physical environmental conditions.

REFERENCE

1. Bhattacharyya, G. S., Roy, G. S. and Dutta, B. K., *Technol*, 3 (1966), 135.

**ERRATUM**

In the paper 'Corrosion of Mild Steel Equipment in Degasification Section in an Ammonia Plant' by Y. K. Varma, G. R. Bhatnagar and A. K. Roy, printed in TECHNOLOGY, Vol. 3, No. 3(1966) p. 157: Corrosion rate should be read as 9.6 in place of 916 corresponding to No. 12 Table 1.

# Physical Studies on Coprecipitated Oxides

## Part 2 : $Fe_2O_3$—$Cr_2O_3$ System

By

SISIR MUKHERJEE AND H. ROY,

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

The influence of precipitating agents as well as minor elements, like aluminium or zinc on the structure and thermal changes of coprecipitated $Fe_2O_3$-$Cr_2O_3$ gels having chromium oxide upto 10 molar per cent has been studied by x-ray diffraction and differential thermal analysis. It has been observed that in the gels an amorphous hydrated iron oxide phase, similar to that of ferric oxide gels precipitated under identical conditions, is formed. This hydrated iron oxide changes to $\alpha$-$Fe_2O_3$ in the range of 300-580°C, but the transformation temperature varies from sample to sample. This variation is found to be due to the difference in the method of preparation of these gels as well as coprecipitation of other minor elements which affect the crystallinity of the amorphous hydrated iron oxide phase. Further, with the decrease of their crystallinity, the mutual action of chromium oxide with iron oxide, as reported by Bhattacharyya et.al, in the transformation of $Fe_2O_3$-$Cr_2O_3$ gels diminishes. The formation of a soild solution around 650°C has also been observed in these coprecipitated gels.

The mixed oxides of the type $Fe_2O_3$-$Cr_2O_3$ are used extensively for conversion of carbon monoxide with steam. Their activity is, however, influenced profoundly by the composition as well as the method of preparation. When precipitated from soluble salts of iron and chromium by alkalis either alone or from their mixture an hydrated iron oxide of type $M_2O_3XH_2O$ (where M is Fe or Cr and X is a digit greater than 1) is usually formed.[1,2] The influence of the method of preparation of such individual gels on the nature of their thermal transformations has been studied by Bhattacharyya et al[3]. They have also studied the effect of composition on the thermal changes of $Fe_2O_3$-$Cr_2O_3$ gels.

It is known that $Fe_2O_3$-$Cr_2O_3$ system with chromium oxide content of about 10 molar per cent is the most effective catalyst for carbon monoxide conversion. But very little is known of the role of the precipitating agents on the structure and thermal transformation of the mixed gels containing such a low percentage of chromium oxide. Again, coprecipitation of this system with a third constituent like aluminium oxide, changes the transformation characteristics of the gels remarkably[3]. As such, it is likely that the coprecipitation of such gels with a small proportion of aluminium or zinc might have an effect on their structures and thermal transformations. Furthermore $\alpha$-$Fe_2O_3$ and $\alpha$-$Cr_2O_3$ are isostructural (hexagonal $a_o$ 5.040 and 4.959 Å respectively)[4] and form a solid solution over the entire range of their composition in the range 550-850°C. But the role of the method of preparation on the formation of such a solid solution from coprecipitated $Fe_2O_3$-$Cr_2O_3$ gels is not known.

In the present investigation, attempts have been made to study the structure and thermal transformations of $Fe_2O_3$-$Cr_2O_3$ gels containing small proportions of chromium oxide with reference to the precipitating agents and other minor elements.

### Experimental

For the preparation of samples, the reagents used were of A.R. grade, and the metal salts were in their nitrate form. A solution of 0.05 M strength (as $R_2O_3$ form, where R=Fe,Cr, Al and in case of Zn as ZnO) in distilled water was prepared with each nitrate and appropriate quantities of these solutions were mixed, wherever necessary, for precipitation. The precipitating agents were added slowly to the solution with stirring at the room temperature (about 26°C) and upto a pH

10. The precipitating agents used were 10 per cent solution of (i) ammonia (by volume), (ii) potassium hydroxide (by wt.) and (iii) a mixture of 10 parts of ammonia solution (10 per cent) with 1 part of saturated lime solution. The precipitate was allowed to settle for about an hour and supernatant liquid was siphoned off. The gels were again agitated with distilled water and allowed to settle. The process was repeated thrice and finally filtered. The filtered mass was then washed several times with distilled water and oven-dried (at 90-95°C) for about 1 hr.

The following samples were prepared: (1) Pure hydrated $Fe_2O_3$ gels precipitated by (i) ammonium hydroxide, (ii) potassium hydroxide and (iii) mixture of ammonium hydroxide and lime solution; (2) Pure hydrated $Cr_2O_3$ gels precipitated by (i) ammonium hydroxide (ii) potassium hydroxide, (iii) mixture of ammonium hydroxide and lime solution; (3) Hydrated $Fe_2O_3$-$Cr_2O_3$ gels (95:5) coprecipitated by (i) ammonium hydroxide, (ii) potassium hydroxide, (iii) mixture of ammonium hydroxide and lime solution; (4) Same as (3) but the composition was 90:10. (5) Hydrated $Fe_2O_3$-$Cr_2O_3$-$Al_2O_3$ or ZnO (94.5:5:0.5 and 89.5:10:0.5) gels coprecipitated by ammonium hydroxide; (6) Same as (5) but the composition was 94:5:1 and 89:10:1; (7) A portion of dried $Fe_2O_3$-$Cr_2O_3$ gels [Samples 3(i) and 4(i)] was triturated with potassium hydroxide (conc.) and saturated lime solution in an agate mortar separately so that each has 0.13 and 0.5 molar per cent $K_2O$ and CaO respectively. These were again oven-dried at 90-95°C for ½hr. The composition of these samples was calculated on the basis of their oxide content and expressed in molar ratio.

The DTA investigations on these samples (Figs 1-3) were performed in a fully automatic and highly sensitive apparatus of Linseis model, using Pt/Pt-Rh (13 per cent) thermocouple and sample holder of a thin platinum cylinder. The reference substance was ignited aluminium oxide. The rate of rise in temperature was maintained at about 10°C/min.

The X-ray powder diffraction photographs of some of the oven-dried gels were taken in a Debye-Scherrer camera of 5.73 cm. diam using Fe-$K_\alpha$ radiation in a Philips PW 1010 unit at 30 KV and 10 mA (Fig.4). Such a pattern of a coprecipitated sample containing aluminium and heated to 220°C has also been taken similarly. The lattice parameter of $\alpha$-$Fe_2O_3$ formed by heating a coprecipitated $Fe_2O_3$-$Cr_2O_3$ (90:10) gel at 550 and 700°C was also determined by the previous procedure[6].

## Results

Ferric oxide gels and those coprecipitated with ferric oxide show one endothermic peak at 140-190°C and one exothermic peak at 300-580°C (Figs 1&2). In case of gels formed by potassium and calcium hydroxide an additional endothermic peak at 300°C appears due to goethite which has been detected in their X-ray patterns. These DTA patterns are similar to the one of the amorphous hydrated iron oxide[1] but one additional peak at 650°C appears in thermograms of $Fe_2O_3$-$Cr_2O_3$ gels and those coprecipitated with aluminium and zinc which is not found in those of ferric oxide gels. Again in case of the mixed gels coprecipitated with small amounts of aluminium or zinc, there is another additional exothermic peak at 210-220°C. (Fig.3), which is not found in the thermograms of ferric oxide and $Fe_2O_3$-$Cr_2O_3$ gels. X-ray diffraction patterns of all these gels show a few broad bands which are similar to each other but those of the mixed gels coprecipitated with aluminium or zinc are broader than the others (Fig.4). Chromium oxide gels show one double-natured endothermic peak at 200-270°C and an exothermic peak at 380-400°C (Fig.1).

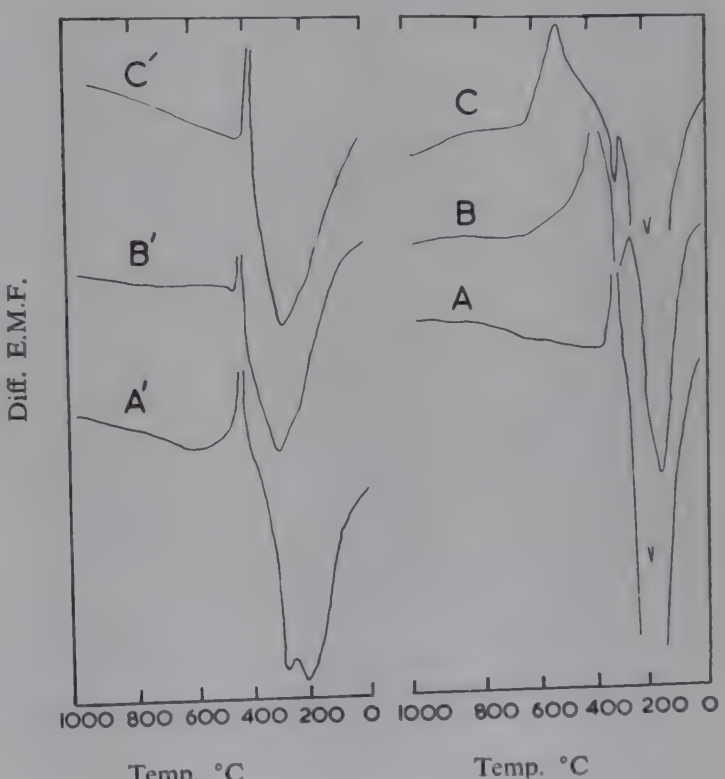



Fig. 1—DTA Thermograms of $Fe_2O_3$ and $Cr_2O_3$ gels.
A & A′ gel precipitated by $NH_4OH$
B & B′ gel precipitated by KOH
C & C′ gel precipitated by $NH_4OH$ containing $Ca(OH)_2$
A, B & C represent $Fe_2O_3$
A′, B′ & C′ represent $Cr_2O_3$

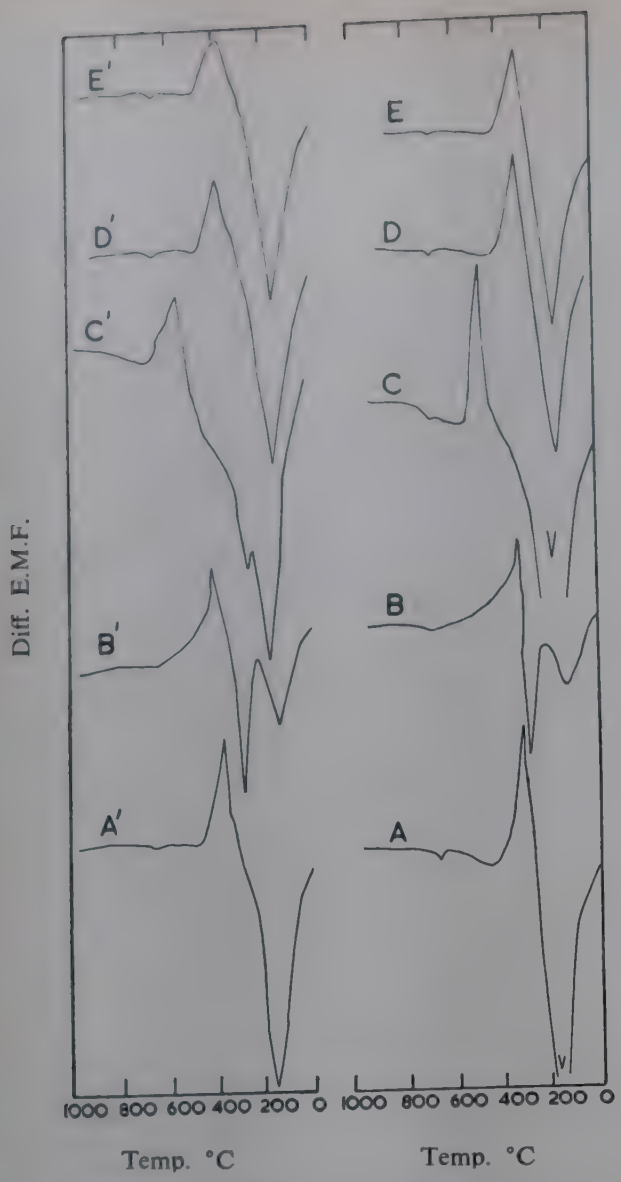



Fig. 2—DTA Thermograms of coprecipitated $Fe_2O_3$-$Cr_2O_3$ gels.

A & A′—precipitated by $NH_4OH$
B & B′—precipitated by KOH
C & C′—precipitated by $NH_4OH$ containing $Ca(OH)_2$
A, B & C—represent $Fe_2O_3$-$Cr_2O_3$ gel containing 5 molar parent $Cr_2O_3$
A′, B′ & C′ represent $Fe_2O_3$-$Cr_2O_3$ gel containing 10 molar per cent $Cr_2O_3$
D, E represent (A) gel mechanically mixed with 0.13 molar $K_2O$ and 0.5 molar cent CaO respectively
D′, E′ represent (A′) gel mechanically mixed with 0.13 molar $K_2O$ and 0.5 molar per cent CaO respectively

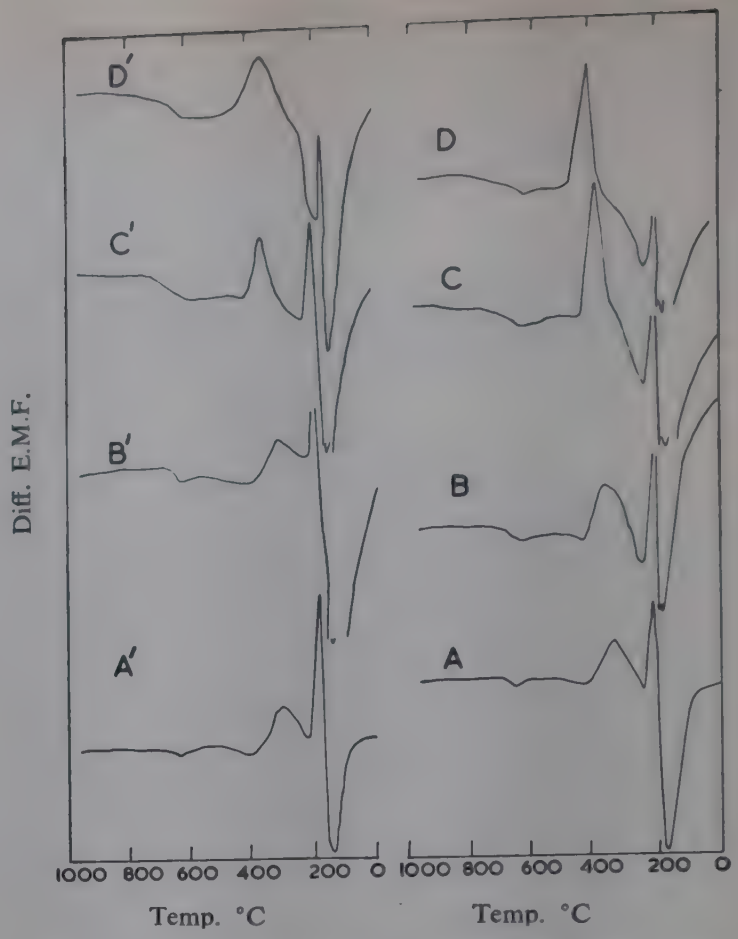



Fig. 3—DTA Thermograms of $Fe_2O_3$-$Cr_2O_3$ gels coprrecipitated with Aluminium and Zinc Oxide by $NH_4OH$

A, B, C & D—$Fe_2O_3$-$Cr_2O_3$ gel containing $Al_2O_3$
A′, B′, C′ & D′—$Fe_2O_3$-$Cr_2O_3$ gels containing ZnO

| | $Fe_2O_3$ | $Cr_2O_3$ | $Al_2O_3$ | | $Fe_2O_3$ | $Cr_2O_3$ | ZnO |
|---|---|---|---|---|---|---|---|
| A | 94.5 | 5 | 0.5 | A′ | 94.5 | 5 | 0.5 |
| B | 94 | 5 | 1 | B′ | 94 | 5 | 1 |
| C | 89.5 | 10 | 0.5 | C′ | 89.5 | 10 | 0.5 |
| D | 89 | 10 | 1 | D′ | 89 | 10 | 1 |

## Discussion

The thermograms of chromium oxide and ferric oxide gels reveal that the exothermic peak temperature of the former is unaffected whereas that of the latter is influenced profoundly by the precipitating agents (Table 1). Similar observation was also made by Bhattacharyya et.al[3]. But a critical examination of their thermograms indicates that this temperature increases with decrease of the ionic radius of the cations present in the precipitating agents (Table 1). The coprecipitated $Fe_2O_3$-$Cr_2O_3$ gels with identical chromium oxide content also show the similar variation. The mutual action of chromium oxide with ferric oxide on the shifting of this peak temperature, as reported by Bhattacharyya et.al[3], has however been observed in these gels also. It may be mentioned here that $Fe_2O_3$-$Cr_2O_3$ gels when mixed mechanically with traces of alkalis ($K^+$ and $Ca^{2+}$) do not show any variation like those precipitated by similar agents (Fig.2). It may, therefore, be inferred that the method of preparation affects the crystallinity of the amorphous hydrated iron oxide phase of those gels.

The presence of an additional exothermic peak at 220°C in the thermograms of coprecipitated $Fe_2O_3$-$Cr_2O_3$ gels containing a small amount of aluminium

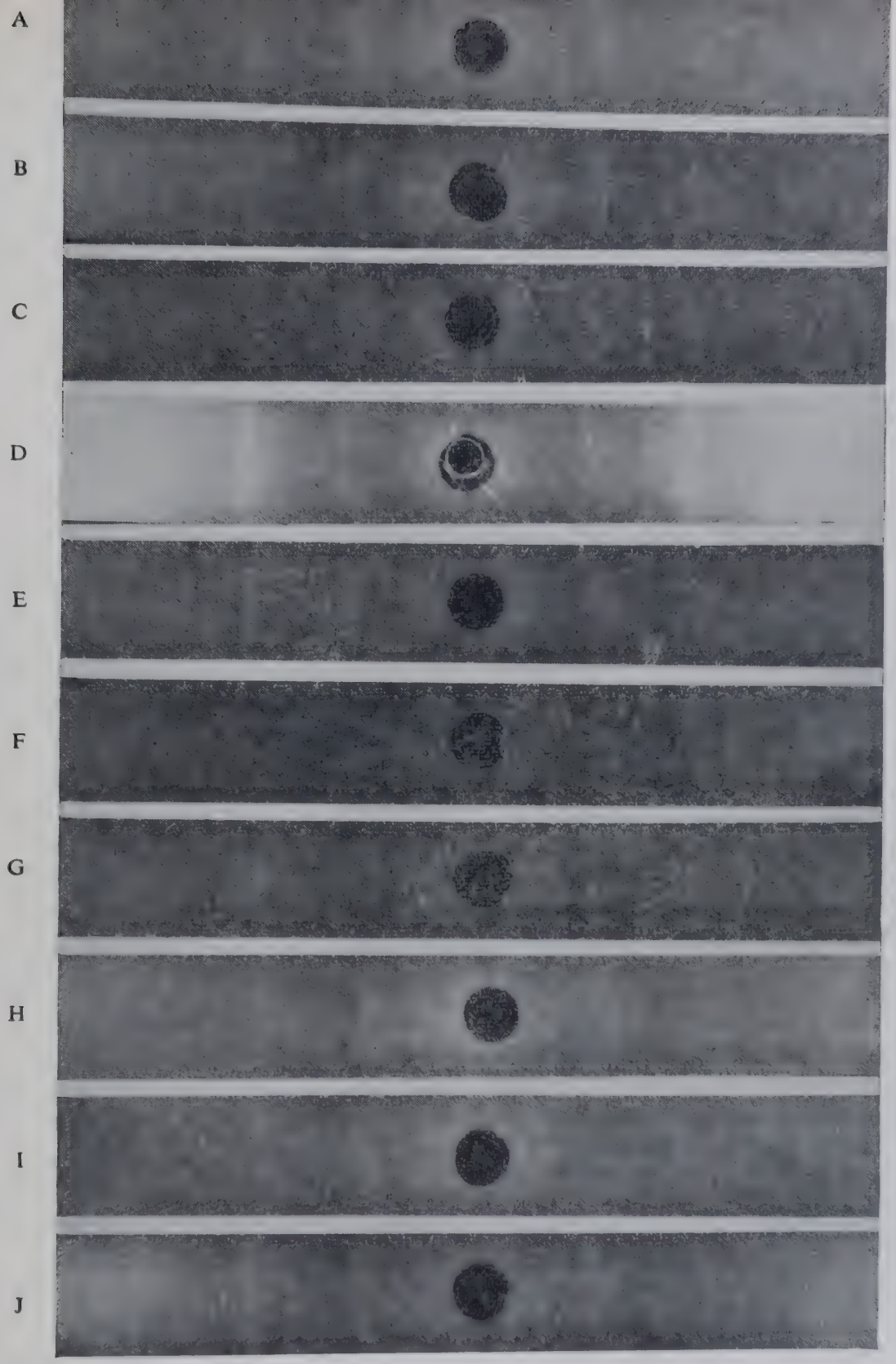



Fig. 4—X-ray Diffraction Pattern of $Fe_2O_3$ and $Fe_2O_3$-$Cr_2O_3$ and those coprecipitated with or without Aluminium or Zinc.

A, B & C—$Fe_2O_3$ gels precipitated by $NH_4OH$, KOH and $NH_4OH$ containing $Ca(OH)_2$

D—$Fe_2O_3$ $Cr_2O_3$ (95 : 5) gel precipitated by $NH_4OH$

E, F & G—$Fe_2O_3$-$Cr_2O_3$ (90 : 10) gel precipitated by $NH_4OH$, KOH and $NH_4OH$ containing $Ca(OH)_2$ respectively

H & I—$Fe_2O_3$-$Cr_2O_3$ gel containing $Al_2O_3$ and ZnO respectively (89 : 10 : 1)

J—$Fe_2O_3$-$Cr_2O_3$-$Al_2O_3$ (89 : 10 : 1) gel heated to 220°C

TABLE 1—EXOTHERMIC PEAK TEMPERATURE OF $Fe_2O_3$, $Cr_2O_3$ AND THEIR COPRECIPITATED GELS

| Precipitating Agent | Cationic Radius, Å | Exothermic Peak Temperature of Gels, °C | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $Fe_2O_3$ | $Cr_2O_3$ | $Fe_2O_3$-$Cr_2O_3$ | | | $Fe_2O_3$-$Cr_2O_3$-$Al_2O_3$ (or ZnO) | | | | | | | |
| | | | | 95:5 A | 90:10 B | B-A | 94.5:5:0.5 | | 89.5:10:0.5 | | 94:5:1 | | 89:10:1 | |
| | | | | | | | $Al_2O_3$ | ZnO | $Al_2O_3$ | ZnO | $Al_2O_3$ | ZnO | $Al_2O_3$ | ZnO |
| $NH_4OH$ | $NH_4^+$ 1.43 | 300 | 380 | 300 | 330 | 30 | 220<br>310 | 220<br>300 | 220<br>360 | 220<br>360 | 210<br>330 | 220<br>330 | 210<br>390 | 220<br>380 |
| KOH | $K^+$ 1.33 | 400 | 400 | 330 | 380 | 50 | — | — | — | — | — | — | — | — |
| $NH_4OH^+$ $Ca(OH)_2$ | $Ca^{2+}$ 1.06 | 520 | 400 | 480 | 580 | 100 | — | — | — | — | — | — | — | — |

or zinc (upto 1 molar per cent as oxide), has been found to be due to transformation of amorphous ferric oxide to its $\alpha$-form (Fig.2). No noticeable shift of this peak temperature with the variation of chromium oxide content of these gels has been observed (Table 1). The reason may be that such coprecipitated gels consist of an hydrated iron oxide of varying degree of crystallinity. The more amorphous form changes to $\alpha$-$Fe_2O_3$ at lower temperature, viz. 220°C, than that of the other. It is also observed that the effect of chromium on the exothermic transformation of $Fe_2O_3$-$Cr_2O_3$ gels is less pronounced when this temperature is low (Table 1). Thus, it is evident that the mutual action of chromium oxide and ferric oxide on the transformation of these gels diminishes as their amorphousness increases.

Again, on heating the coprecipitated gels at 700°C, a change of the lattice parameter ($a_o$ of $\alpha$-$Fe_2O_3$ formed by thermal transformation) has been observed. In case of a gel containing 10 molar per cent of chromium oxide $a_o$ changes from 5.040 Å at 550°C to 5.039 Å at 700°C. According to Dicerbo et al[4], the former value corresponds to that of pure $\alpha$-$Fe_2O_3$ and the latter to that of a solid solution with about 10 molar per cent of chromium oxide. The appearance of a weak endothermic peak at about 650°C in the thermograms of all the coprecipitated gels is, therefore, due to the formation of this solid solution. Such a change in the lattice parameter value cannot be detected in gels containing chromium oxide less than 10 molar per cent as error in the measurement technique may override the actual figure[6].

**Acknowledgement**

Thanks are due to Dr. K. R. Chakravorty, General Manager, Planning & Development Division, for his keen interest in this problem and to Dr. B. K. Banerjee of the Physical Research Wing for his encouragement.

REFERENCES

1. MacKenzie, R. C. (Ed.), *Differential Thermal Investigation of Clays* (Min. Soc., London.), 1957.
2. Bhattacharyya, S. K., Ramachandran, V. S. and Ghosh, C., *Internal. Cong. on Catalysts*, 1957.
3. Bhattacharyya, S. K. and Ganguli, N. D., *Proc. Nat. Inst. Sci. India*, **27** (1964), 588.
4. Dicerbo, R. K. and Seybolt, A. U., *J. Amer. Ceram. Soc.*, **42** (1959), 430.
5. Pouillard, E., *Ann. Chim.*, **5** (1950), 164.
6 Mukherjee, S. and Roy, H., *Technol.* **3** (1966), 63.

# Corrosion in Water Scrubber in an Ammonia Plant

By

K. M. Verma, M. P. Gupta, S. C. Varma, H. Ghosh and A. K. Roy,

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

In the carbon dioxide scrubbing section of the ammonia plant at Sindri Fertilizer Factory, some blisters with partings of the metal underneath were observed on the inside surface of the shell of the water scrubber. Investigation have been carried out on the causes of the failure.

In the ammonia plant at the Sindri Fertilizer Factory the synthesis gas having the following composition (%), viz. $H_2$ 49.6, CO 4.0, $CO_2$ 29.3, $N_2$ 16.5, $CH_4$ 0.4, Argon 0.2 and $H_2S$ traces, is compressed to a pressure of 280 lbs/sq. in. and sent to six water scrubbers in parallel for removal of carbon dioxide by scrubbing with water. In one of these scrubbers some blisters were observed on the inside surface of the shell plate in an area opposite to the gas inlet pipe. The scrubber is a packed tower having the following specifications.

| Dimensions | | Design Data | |
|---|---|---|---|
| Height | 72 ft. 6 in. | U.T.S. | 55,000 psi |
| Internal diam. | 93 in. | Elongation | 32% |
| External diam. | 96 in. | Material | ASTM x-SA-70-42 type of steel |
| | | Max. Working pressure | 280 psi. |
| | | Design temperature | 100°F |
| | | Total weight of the tower including Raschig ring and water | 4,02,3000 lbs. |

## Experimental

*Tests and Observations*: The entire area opposite to the gas inlet was scanned by ultrasonic flaw detector, and in all seven blisters were detected but according to ASTM standards only three were of significance. A circular piece, 4 inches in diameter, containing a blister was cut out for examination from the shell from a location opposite to the gas inlet pipe. A cut through the blister (Fig. 1) revealed a large cavity about 6 mm. below the inside surface in the shape of a segment of a sphere. The cavity had a width of 6 mm. at the centre and a diameter of 57 mm. The section also revealed fine cracks penetrating the 6 mm. thickness below the surface. Chemical analysis, mechanical tests and metallographic examination were carried out with the samples cut out from the inside as well as outside portions of the shell plate. The results are given below (Table 1).

TABLE 1—Characteristics of a Sample Piece From the Affected Portion

| Chemical Analysis, % | | Mechanical Properties | | | |
|---|---|---|---|---|---|
| | | Description of the sample | U.T.S., psi | Reduction in Area, % | Elongation, % |
| C | 0.27 | 1. In longitudinal direction | 62,912 | 50.9 | 36.4 |
| Si | 0.01 | | | | |
| S | 0.056 | 2. In Transverse direction | 63,845 | 50.9 | 35.2 |
| P | 0.036 | Hardness | 120 BHN | | |
| Mn | 0.77 | | | | |

*Metallographic Examination:* Several samples from the affected and non-affected regions, from the outer as well as inner portions, were subjected to metallographic examination. All the samples showed the normal ferrite-pearlite structure characteristic of carbon steel. The outer portions of the shell on which the blister formed did not show any cracks but the portions even slightly away from the visible crack showed numerous small cracks on polishing. The cracks were highly branched and both transgranular and intergranular (Fig. 2). The cracks did not have any definite orientation with respect to the directions of rolling of the grains and were randomly distributed.

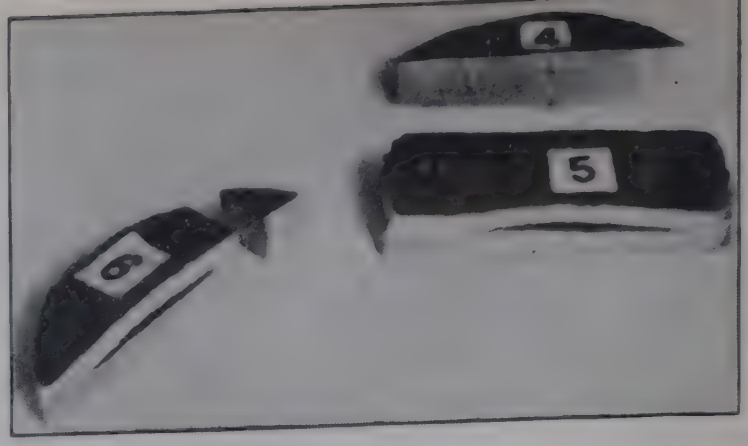



Fig. 1—Circular piece cut out for examination showing the Blister and the Cavity underneath the Inside Surface of the Shell of the Water Scrubber.

**Discussion**

Chemical analysis, mechanical properties and metallographic structure did not indicate any deterioration or defect in the material either due to chemical action or to other external factors. The blister formation and parting of the metal underneath could be explained as under: At a point opposite the $CO_2$ inlet, the concentrations of carbonic acid would be the highest and also the pH of the solution would be low—about 3.5 at a pressure of 280 psi. Under these conditions, atomic hydrogen would be produced according to equation (1). The formation

$$CO_2+H_2O+Fe = FeCO_3+2H \quad (1)$$
(atomic hydrogen)

$$2H = H_2 \quad (2)$$
(molecular hydrogen)

of molecular hydrogen according to equation (2) would be retarded even by traces of hydrogen sulphide[1], which would get dissolved in the scrubber water under pressure, and thus atomic hydrogen would diffuse into the interior of the shell and accumulate there. The atomic hydrogen would be gradually liberated as molecular hydrogen in the internal cavities as a result of which a great pressure would develop inside the metal and the gas would finally escape causing a blister on the inner surface and the parting of the metal underneath.

**Acknowledgements**

The authors wish to thank Dr. K. R. Chakravarty, General Manager, for his interest in this work. Thanks are also due to Mr. K. C. Banerji, Deputy Superintendent, Physical Reserch Wing, for supplying the results of Ultrasonic tests and the photograph (Fig. 1).

REFERENCE

1. Marsh, G. A., *Corrosion*, **10** (1954), 101.

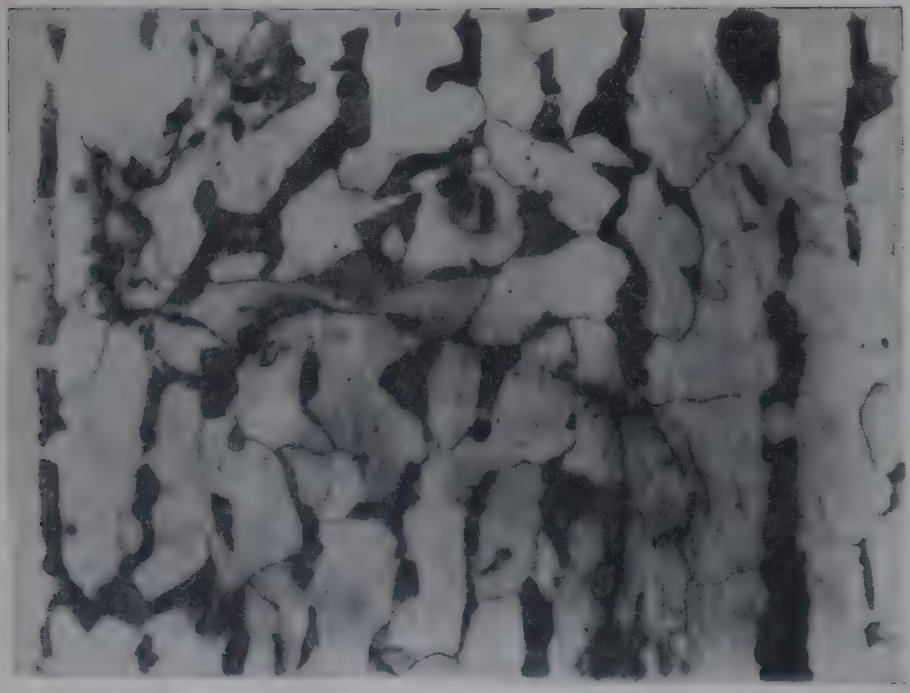


Fig. 2—Photomicrographs of the Inner side of the Carbon Steel Water Scrubber Shell. Transverse Section shows the normal ferrite-pearlite structure with multiple highly branched intergranular and transgranular cracks. (×450)

# Studies on Corrosion Cracking of Stainless Steel Vessels of an Air Liquefaction Plant

By

Ajit Roy, C. V. Srinivasan, P. K. Ghosh and C. Aravindakshan,

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

Investigations by x-ray diffraction, thermomagnetic and electron microscopic techniques on samples collected from the leakage points of an air liquefaction plant revealed that cracking of stainless steel vessels was due to stress-corrosion caused by residual stresses and chloride environments.

During the pneumatic testing of different sections of stainless steel vessels of an air liquefaction plant* number of leaks at the following sections were detected: (a) high pressure column (95 leaks), (b) low pressure column (6), (c) Crude argon column (5) and (d) Nitrogen exchanger (2). These leakage points were very near to the welds, i.e. within 2″ from the welding seam, except for one which was 3″ away.

An examination of the high pressure column at site showed that there were five double-seam weldings with backing ring and seven single-seam weldings. The total seam portions done with the backing rings had a width of $2\frac{1}{4}$″ on the inside surface of the vessel and $\frac{1}{2}$″ width on the outside; the ring was welded with 3/16″ plate. It was also observed that there were extensive bluish-white deposits at the circumference as well as on the copper sieve plates which were made to fit to the cylindrical stainless steel column. The same deposits were also found on the inside wall of the stainless steel column where the copper sieve plates were originally fitted. Therefore, a detailed investigation was taken up on the metal samples and bluish-white deposits collected from the affected regions of the high pressure column to reveal the causes of corrosion and leakages. The techniques employed were x-ray diffraction, electron microscopy and thermomagnetic methods.

* Fertilizer Corporation of India Ltd., Trombay

## Experimental

The following samples were collected from the high pressure column: (1) shell edge near the welding; (2) top backing ring, (3) longitudinal weld with shell plate, (4) shell plate by the side of backing ring and (5) weld on the backing ring. In each case the following three regions were chosen for examination: weldmet, material adjacent to the weld and parent metal far away from the weld.

The specimens were prepared in different ways for different types of investigations. Metal dusts were obtained by mild filing of the predetermined location of the samples and these were used to obtain x-ray diffraction photographs using Debye-Scherrer type powder camera with Fe $K_\alpha$ (filtered) radiation. The same filing dusts were used in a thermomagnetic balance for identification of phases. For electron microscopy examination, each sample surface was polished, etched and carbon replicas were stripped in a solution of 10 per cent nital.

## Results

Prior to investigation, spectroscopic analyses of all the samples were done to confirm the specification (AISI-304 type).

(1) *X-ray Diffraction Analysis:* The x-ray diffraction photograph of the bluish-white deposit showed it to be $CuCl_2$. As the origin of this chloride was unknown, it was thought worthwhile to examine the brazing flux

Fig. 1—X-Ray Diffraction Photographs of Stainless Steel Sample No. 3 using FeK$\alpha$ Radiation and 11.46 cm. diam. Powder Camera.

A—Weldmet; B—Material Adjacent to the Weld; C—Parent Metal; D—Back Reflection Photograph of Austenitic Steel Block for Comparison.

from which the chloride could have come if the joint had not been cleaned properly after the brazing operations. Actually, ammonium chiorozincate was identified as the crystalline phase in the brazing flux.

The x-ray diffraction photographs of the parent metal far away from the weld, of all five samples, showed austenite as the only crystalline phase (Table 1). But, the diffraction photograph of filing dusts collected from the material adjacent to the weld and weldmets revealed small amounts of ferrite along with the austenite. In fact, in the case of samples 3 and 5, the ferrite phase was estimated[1] to be around 1 per cent on the material adjacent to the weld and around 5-6 per cent on the weldmets.

The photographs also indicated lattice strain, shown by the broadening of the higher angle lines of the diffraction photograph of austenite structure (Fig. 1), which was increasing from the parent metal towards the weldmets.

(2) *Thermomagnetic Analysis:* The samples were analysed by the thermomagnetic balance fabricated here[2]. The results of analysis of all the samples from parent metal, adjacent to the weld and weldmet, corroborate the findings of the x-ray diffraction analysis in the crystalline phase identification as well as estimation of ferrite phase on the material adjacent to the weld and on the weld (Fig. 2 and Table 2). In addition, in case of samples 1 and 3 an unidentified phase having a peak at 425°C was detected from the material adjacent to the weld. The weldmet and material adjacent to the weld of sample 3 showed traces of cemenitite and also Haegg carbide along with the unidentified phase, whereas the corresponding region of sample 5 showed the presence of cementite only.

(3) *Electron Microscopic Examination:* The carbon replicas of the parent metal of all the five samples examined under the electron microscope revealed that the structure was austenite. But, the replicas obtained from the material adjacent to the weld from samples 3 and 5 showed some precipitation along the austenite grain boundaries (Fig. 3A). The occurrence of the precipitate was denser at regions closer to the weld and highest on the weld. The increased precipitation along the slip planes formed a linear array (Fig. 3 B).

**Discussion and Conclusion**

The results of spectroscopic analysis of all the stainless steel samples fall within the specification of material of construction, i.e. AISI type **304. This was further confirmed by the presence of only austenite phase in the parent metal as shown by x-ray and thermomagnetic analysis.

The identification of $CuCl_3$ in the bluish-white deposits by x-ray diffraction showed that chloride has not been removed completely from the copper sieves after the brazing operation. This chloride formation could have happened only from the brazing flux which was identified as ammonium chlorozincate.

The line broadening on the higher angle side of diffraction photographs of austenite structure indicated the strain on the austenite lattice, which was found to be increasing towards the weldmets (Fig. 1). This effect on the austenite lattice would have been caused by the thermal stresses set up by uneven cooling rate of welded sections having their sheets welded on to comparatively thick backing ring.

The precipitation of ferrite phase in an increasing amount towards the weldmet by x-ray and thermo-

** A type of stainless steel standardized by the American Iron & Steel Institute.

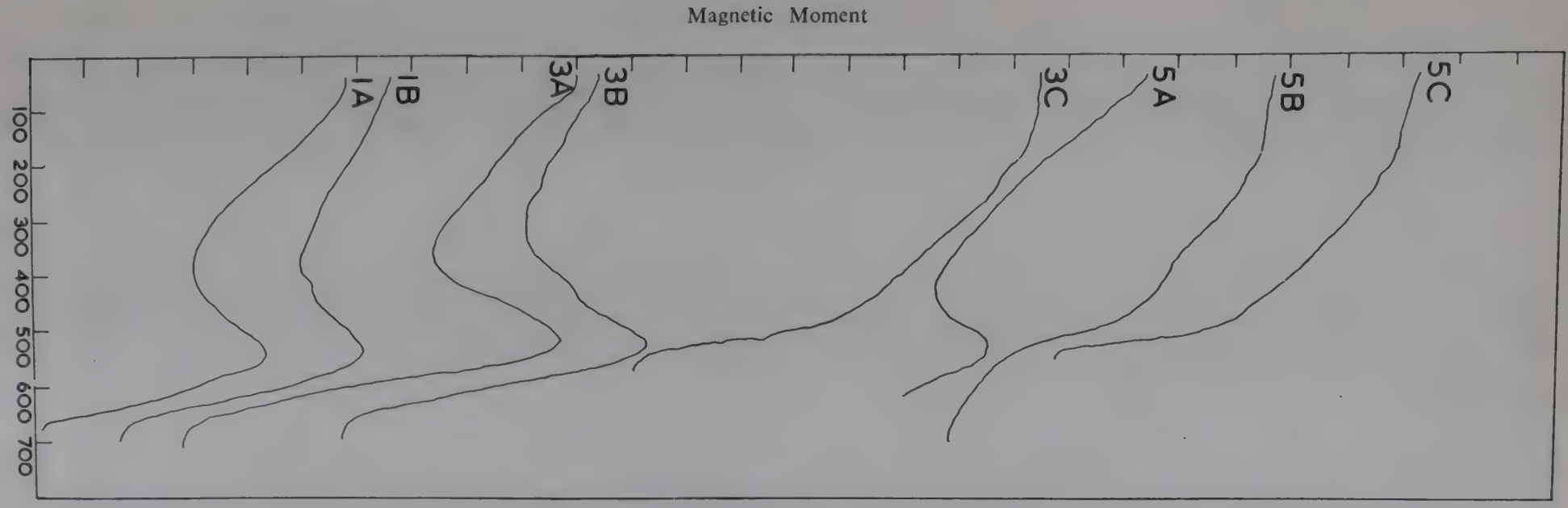



Fig. 2—Thermomagnetic Curves of Stainless Steel Samples.

TABLE 1

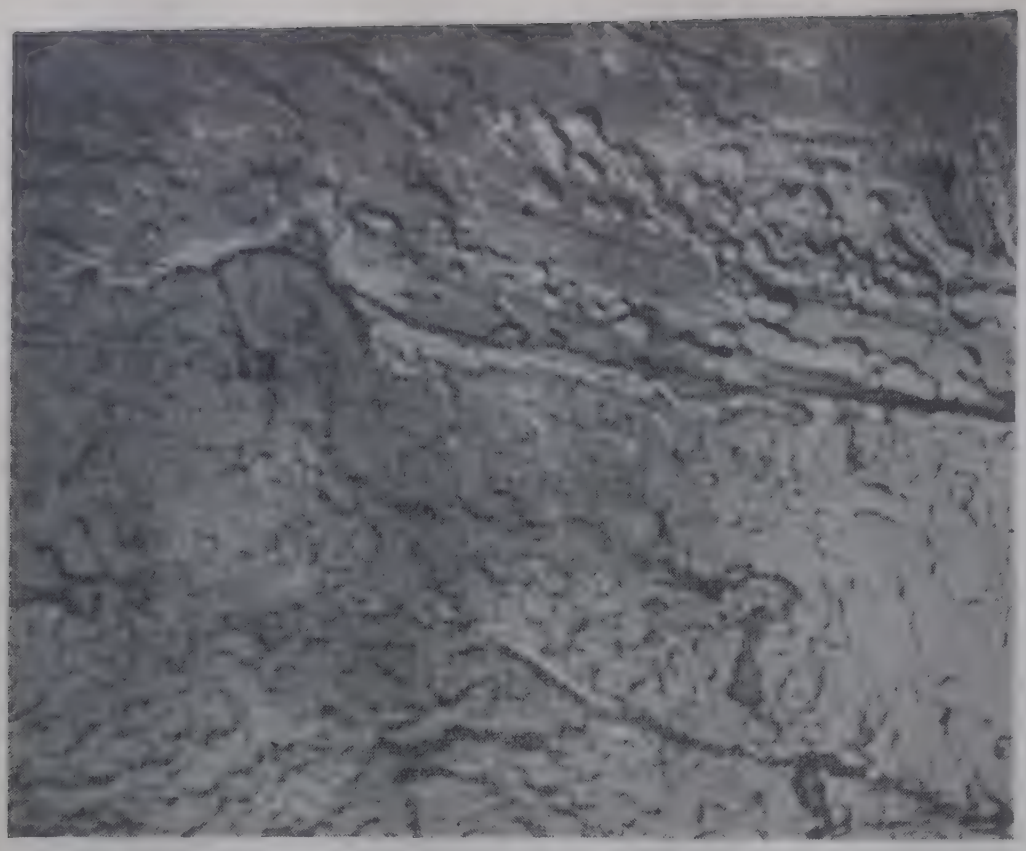
X-RAY DATA OF S. S. SAMPLES, CORROSION DEPOSIT AND BRAZING FLUE

| Parent metal* | | Metal Adjacent to the Weld** | | Weldmet* | | γ-Fe ASTM, 5-0717 | | ∝-Fe ASTM, 6-0696 | | Deposit | | $Cu Cl_2$ ASTM, 1-0185 | | Brazing Flux | | $Zn Cl_2 3NH_4 Cl$ ASTM, 2-0548 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| d (Å) | Int. | d (Å) | Int. | d (Å) | Int. | d (Å) | Int. | d (Å) | Int. | d (Å) | Int. | d (Å) | Int. | d (Å) | Int. | d (Å) | Int. |
| 2.086 | s | 2.082 | s | 2.083 | s | 2.08 | 100 | | | 5.8 | s | 5.7 | 100 | 5.77 | mw | 5.8 | 80 |
| | | 2.030 | vvw | 2.029 | vw | | | 2.027 | 100 | | | 5.4 | 3 | 5.01 | w,br | 5.10 | 25 |
| 1.807 | w | 1,810 | w | 1.809 | w | 1.80 | 80 | 1.433 | 19 | 4.02 | vvw | 4.01 | 7 | | | 4.95 | 25 |
| | | | | | | | | | | 3.43 | vw | 3.42 | 42 | 4.30 | vvw | 4.32 | 5 |
| 1 270 | mw | 1.267 | mw | 1.271 | mw | 1.27 | 50 | | | 2.90 | ms | 2.90 | 66 | 4.06 | vvw | 4.05 | 5 |
| | | | | 1.169 | vvw | | | 1.170 | 30 | 2.62 | vw | 2.62 | 10 | 3.82 | vvw | 3.85 | 5 |
| 1.084 | ms | 1.083 | ms | 1.085 | ms | 1.083 | 80 | | | 2.358 | m | 2.36 | 66 | 3.52 | vvw | 3.52 | 5 |
| 1.038 | mw | 1.037 | mw | 1.039 | mw | 1.037 | 50 | | | | | 2.20 | 3 | 3.16 | s | 3.15 | 100 |
| | | | | | | | | | | | | 2.00 | 3 | 2.94 | vvw | 2.95 | 5 |
| | | | | | | | | | | 1.855 | w | 1.86 | 33 | 2.87 | vvw | 2.88 | 15 |
| | | | | | | | | | | 1.802 | vw | 1.80 | 20 | 2.76 | vvw | 2.76 | 5 |
| | | | | | | | | | | 1.708 | vw | 1.70 | 20 | 2.73 | vvw | 2.72 | 5 |
| | | | | | | | | | | 1.650 | vw | 1.64 | 17 | 2.462 | w | 2.46 | 60 |
| | | | | | | | | | | 1.595 | vvw | 1.58 | 7 | | | 2.34 | 2 |
| | | | | | | | | | | 1.500 | vvw | 1.49 | 7 | 2.061 | w | 2.05 | 40 |
| | | | | | | | | | | 1.448 | vw | 1.44 | 20 | | | | |

s-strong, ms-medium strong, m-medium, mw-medium weak, w-weak, vw-very weak and vvw-very very weak.

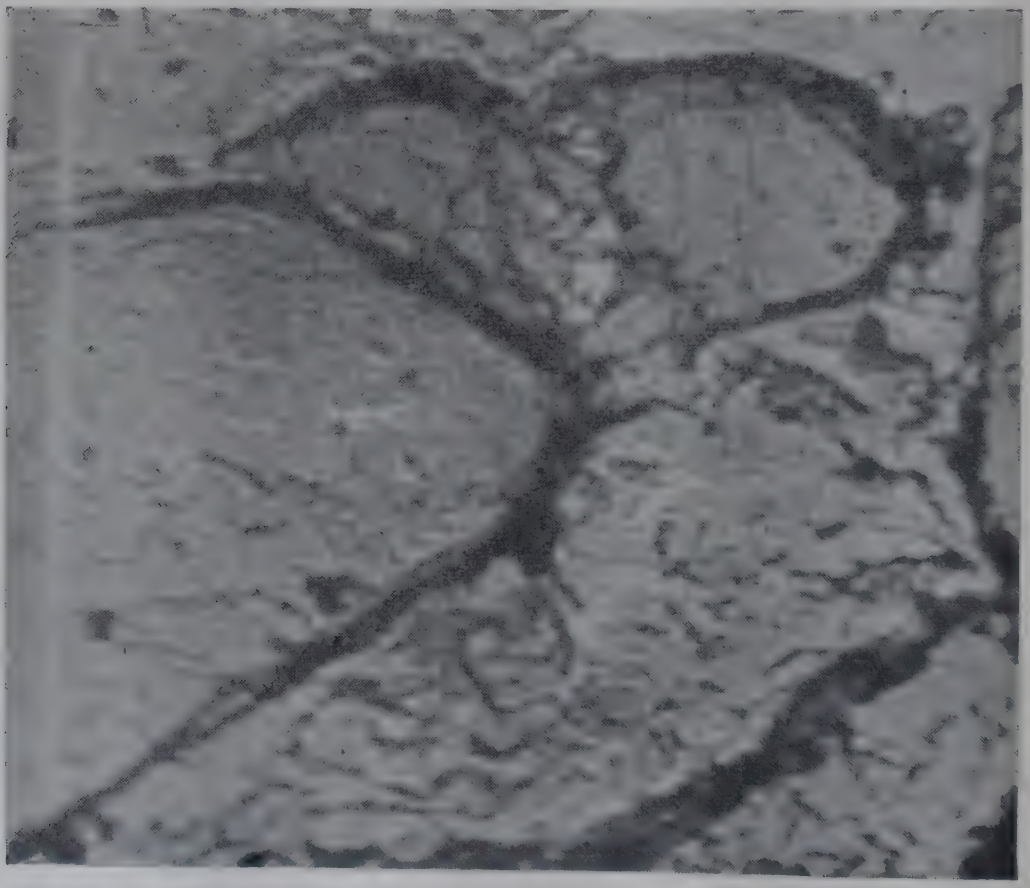
*-Diffraction photograph of parent metal of all samples are identical.

**-Diffraction photograph of metal adjacent to the weld and weldmet of sample Nos. 3 and 5 were identical in spacing and almost alike in intensity.



a—Material adjacent to the weld showing precipitation along grain boundaries.

(×30,000)



b—Weldmet showing increased density of precipitation forming a linear array.

(×30,000)

Fig. 3—Electron Micrographs of Stainless Steel Sample No. 3.

TABLE 2—INTERPRETATION OF THE THERMOMAGNETIC CURVES OF THE S. S. SAMPLES

| Sample No* | Cementite (Curie pt. at 210°C) | Haegg Carbide (Curie pt. at 225°C) | Unidentified Phase (peak at 425°C) | Ferrite Alloy (Curie pt. at 640°C) | Austenite Alloy (peak at 550°C) |
|---|---|---|---|---|---|
| 1A | — | — | — | — | Present |
| 1B | — | — | Little | — | Present |
| 2A | — | — | — | — | Present |
| 3A | — | — | — | — | Present |
| 3B | Traces | Traces | Little | — | Present |
| 3C | Traces | — | Traces | Present (about 5%) | Present |
| 4A | — | — | — | — | Present |
| 5A | — | — | — | — | Present |
| 5B | Traces | — | — | Present (about 1%) | Present |
| 5C | Traces | — | — | Present (about 5%) | Present |

*The letters, A, B & C, following the numbers indicate that they are of parent metal, materials adjacent to the weld and weldmet respectively.

magnetic analyses, detection of traces of carbide precipitation by thermomagnetic analysis and evidence of precipitation along slip planes in regions close to welds shown by electromicrograph also suggest high heating and residual stresses left over due to uneven cooling of the double-seam welded sections.

Stress concentrations by the residual stresses can produce preferencial chemical dissolution of solute stoms from the slipped regions [3–5]. This initiates dislocations in a linear array providing localized sites for preferential electrochemical attack. The preferential electro-chemical reaction generates a series of microcracks which link together to produce a slit capable of propagating under applied or residual stresses[6, 7]. This type of stress-cracking was further widened at the tip[8, 9] by the presence of chloride and the material has failed by transgranular stress-corrosion cracking.

**Acknowledgements**

The authors are grateful to Dr. K. R. Chakravorty for his keen interest in the problem and for permission to publish this paper. Their thanks are due to Dr. B. K. Banerjee, Addl. Superintendent, and Sri. K. C. Banerji, Deputy Superintendent, for guidance, and also to Sarbasri K. C. Singhal and N. L. N. Murthy for their co-operation.

REFERENCES

1. Arvindakshan, C., Roy, Ajit and Banerjee, B. K., *Technol*, (Communicated).
2. Pandey, S. N., Murthy, N. L. N., and Ghosh, P. K., *Technol*, **2** (1965), 220.
3. Bakish, D. and Robertson, W. D., *Acta. Met.*, **3** (1955), 513.
4. Swann, P. R., *Corrosion*, **19** (1963), 102t.
5. Nielsen N. A., *Ibid*, **20** (1964), 104t.
6. Douglass, D. L., Thomas, G. R., and Roser, W. R., *ibid*, 15.
7. Tromans, D. amd Nutting, J., *Ibid*, **21** (1965), 143.
8. Nielsen, N. A., *Physical Metallurgy of Stress Corrosion Fracture*, (Ed. Thorn N. Rhodin) [Interscience Publishers Inc., New York], 1959, 121.
9. Pickering, H. W., Beck, F. H. and Fontana, M. G., *Corrosion*, **18** (1962), 230t.

# Crystallographic Data For Dimethylene Triurea

By

C. Aravindakshan and B. K. Banerjee,

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

Dimethylene triurea $(NH_2CONH)_2(CH_2)_3$ has been extracted as cold water-insoluble portion of a urea-form fertilizer, and its unit cell dimensions and space group have been determined. It belongs to the orthorhombic system having $a_o=12.50$, $b_o=8.22$ and $C_o=9.09$ Å with space group P $222_1$ or P $22_12_1$.

It has been found that acid catalysed condensation products of urea with formaldehyde under controlled molecular ratio, pH and temperature yield long chain molecules of methylene ureas[1–3]. These compounds, known as urea-form fertilizers, have been advocated for long season crops because of their low solubilities and therefore slow rate of releasing nitrogen to the soil and plants.

During a systematic study* on the type and nature of products of urea-form fertilizers obtained by different process variables, a cold, water-insoluble product was extracted from all the urea-forms prepared with molecular ratio of urea to formaldehyde, (U/F), 1.5:1 to 2:1 at pH-4 and at room temperature. When an attempt was made to identify this product by comparing its x-ray powder data with those of the compounds reported so far, it was found that it did not agree in intensity and 'd' values of the powder lines with any of the compounds. Therefore, it was decided to determine its unit cell dimensions and space group in order to identify the type of methylene urea to which this insoluble compound belongs.

For indexing the powder lines and determination of unit cell parameters the reciprocal lattice method[4] was followed. The $\frac{I}{d^2_{hkl}}$ or $Q_{hkl}$ values were obtained for all $d_{hkl}$ values and the differences, i.e. Q's for all observed $Q_{hkl}$ values were tabulated. On an inspection of this table it was found that the values 0.0063, 0.0567, 0.0122, 0.1096, 0.0145, 0.0566 occurred many times. Assuming any of these values or their combinations as the unit cell edges of the reciprocal lattice, $Q_{hkl}$ values for various reflections were calculated for the isometric, tetragonal or hexagonal systems, and these were compared with the observed values. As all the observed $Q_{hkl}$ values could not be satisfactorily indexed by any of these lattices, these were tried for an orthorhombic system. Then it was found that the values 0.0063, 0.0122 and 0.0145 could be fed into to get all observed $Q_{hkl}$ values. Further refinement yielded the following values 0.0064, 0.0121 and 0.0148, and the agreement between the observed and calculated $Q_{hkl}$s were found to be quite good (Table 1). Therefore, the latter values were adopted as final and the unit cell parameters were calculated to be $a_o=12.50$, $b_o=8.22$ and $C_o=9.09$ Å.

In order to decide the space group, a survey for the systematic absent reflections was made. The data showed that the reflections of the type (oo *l*) with *l* odd were absent. The reflections of the type OkO with k odd also seemed to be absent. But the observed $Q_{hkl}$ value of the diffraction line at 2.745 Å corresponds to both 030 and 222 reflections which gave exactly the same calculated $Q_{hkl}$ value. As it is not possible to decide from powder diffraction data whether the 2.745 Å diffraction line was only due to either one or both of the above reflections the condition that the reflections of the type with k odd were also absent has not been confirmed. Therefore, the space group was deduced to be either P $222_1$ or P $22_12_1$.

* The results of this study will be published later.

TABLE 1

TABLE 1—X-RAY DATA OF THE COLD WATER-INSOLUBLE PRODUCT

| Sl. No. | Int. | d (Å) | $Q_{hkl}$ obs. | $Q_{hkl}$ calc. | Difference | hkl |
|---|---|---|---|---|---|---|
| 1. | vvw | 12.0 | 0069 | 0064 | −0005 | 100 |
| 2. | vvw | 6.0 | 0278 | 0269 | −0009 | 011 |
| 3. | vvw | 5.49 | 0332 | 0333 | +0001 | 111 |
| 4. | vvw | 5.17 | 0374 | 0378 | +0004 | 201 |
| 5. | | 4.54 | 0485 | 0484 | −0001 | 002 |
| 6. | vvw | 4.34 | 0531 | 0525 | −0006 | 211 |
| 7. | ms | 4.19 | 0570 | 0576 | +0006 | 300 |
| 8. | vw | 4.11 | 0592 | 0592 | .0000 | 020 |
| 9. | m | 3.99 | 0628 | 0632 | +0004 | 012 |
| 10. | vvw | 3.88 | 0664 | 0656 | −0008 | 120 |
| 11. | vw | 3.73 | 0719 | 0713 | −0006 | 021 |
| 12. | vw | 3.42 | 0855 | 0848 | −0007 | 220 |
| 13. | vw | 3.24 | 0953 | 0969 | +0016 | 221 |
| 14. | m | 3.13 | 1021 | 1024 | +0003 | 400 |
| 15. | vvw | 2.95 | 1149 | 1153 | +0004 | 103 |
| | | | | 1145 | +0006 | 401 |
| 16. | w | 2.90 | 1189 | 1172 | −0017 | 410 |
| 17. | vvw | 2.85 | 1231 | 1237 | +0006 | 013 |
| 18. | vvw | 2.745 | 1327 | 1332 | +0005 | 222 |
| | | | | 1332 | +0005 | 030 |
| 19. | vvw | 2.720 | 1352 | 1345 | −0007 | 203 |
| 20. | vvw | 2.615 | 1462 | 1454 | −0008 | 031 |
| 21. | vvw | 2.595 | 1485 | 1493 | +0008 | 213 |
| 22. | w | 2.455 | 1659 | 1656 | −0003 | 412 |
| | | | | 1666 | +0007 | 322 |
| | | | | 1665 | +0006 | 303 |
| 23. | vw | 2.435 | 1687 | 1709 | +0022 | 231 |
| 24. | vvw | 2.400 | 1736 | 1737 | +0001 | 421 |
| 25. | vvw | 2.270 | 1941 | 1936 | −0005 | 004 |
| | | | | 1937 | −0004 | 223 |
| 26. | vvw | 2.150 | 2163 | 2148 | −0015 | 114 |
| 27. | vvw | 2.075 | 2323 | 2313 | −0010 | 521 |
| 28. | vvw | 2.001 | 2498 | 2489 | −0010 | 041 |
| 29. | vvw | 1.910 | 2741 | 2746 | +0005 | 241 |
| 30. | vvw | 1.865 | 2875 | 2896 | +0021 | 620 |
| 31. | vvw | 0.740 | 3303 | 3281 | −1122 | 523 |
| | | | | 3283 | −0020 | 701 |
| 32. | vvw | 1.610 | 3858 | 3849 | −0009 | 721 |
| 33. | vvw | 1.515 | 4357 | 4356 | −0001 | 006 |
| 34. | vvw | 1.490 | 4504 | 4515 | +0011 | 234 |
| 35. | vvw | 1.465 | 4659 | 4672 | +0013 | 640 |
| 36. | vvw | 1.435 | 4856 | 4864 | +0008 | 344 |
| 37. | vvw | 1.389 | 5183 | 5184 | +0001 | 900 |
| 38. | vvw | 1.305 | 5872 | 5898 | +0016 | 921 |
| 39. | vvw | 1.288 | 6028 | 6032 | +0004 | 262 |
| 40. | vvw | 1.208 | 6853 | 6865 | +0012 | 923 |

s—strong, ms—medium strong, m—medium, w—weak, vw—very weak, vvw—very very weak.

The above x-ray powder data were obtained with CuK$\alpha$ radiation using a crystal monochromator and a guinier camera.

Having, thus, ascertained the unit cell parameters and the space group, the density was determined by the flotation method in a liquid mixture of carbon disulphide and carbon tetrachloride. The density was found to be 1.46. Now, to get this density for a compound having the unit cell parameters determined and stated earlier, only dimethylene triurea among the methylene ureas with four molecules per unit cell is possible. Then the calculated density for dimethylene triurea is 1.47.

Thus, the cold water-insoluble product, extracted from the urea—form fertilizers prepared with U/F mole ratios of 1.5:1 to 2:1 at pH 4 and at room temperature, showed it to be dimethylene triurea. Its unit cell parameters are $a_o$=12.50, $b_o$=8.22 and $C_o$=9.09Å with space group either P $222_1$ or P $22_12_1$ belonging to the orthorhombic system.

**Acknowledgement**

The authors thanks are due to Dr. K. R. Chakravorty, General Manager, for his permission to publish this paper.

REFERENCES

1. Kodowaki, H., *Bull. Chem. Soc. (Japan)*, **11** (1936), 284.
2. Clark, K. G., Yee, J. Y. and Love, K. S., *Indus. Engng. Chem.*, **40** (1948), 1178.
3. Clark, K. G., Yee, J. Y., Love, K. S. and Boyd, T. A., *Ibid*, **43** (1951), 871.
4. Azaroff, L. V. and Buerger, M. J., *The Power Method in X-ray Crystallography*, (McGraw Hill Book Co. Inc. New York), 1958.

# Examination of the Core Structure of Granular Calcium Ammonium Nitrate

By

M. Samaddar and H. Roy,

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

A microscopic examination of the core structure of some calcium ammonium nitrate granules has been made to elucidate the origin of caking in those samples. It has been observed that caking occurs in the surface moisture zone of those granules due to subsequent recrystallization as a result of which cementing takes place at such zones. This surface moisture zone extends when ammonium nitrate particles are more towards the surface than at the centre of the core structure of the granules as well as when their diluent particles are coarser.

## Introduction

Caking of granular fertilizers is due to bonding of their granules by crystal of soluble salts that are formed on their surfaces[1]. In the case of calcium ammonium nitrate (CAN), the granules have been found to be more caked when their surface moisture zone is large[2]. Again, the area of this surface moisture zone increases with increase of their apparent bulk volume when compared among samples of similar composition and moisture content[2]. But variation of their apparent bulk volume is due to the differences mainly in the size of the pores inside the core. Some studies have already been made as regards the caking characteristics of CAN in relation to the composition, nature and size distribution of the diluent particles, coating agents, etc.[3] but very little is known on the core structure of the granules and its relation with the caking.

Considering this, an attempt has been made in the present investigation to examine the core structure of some CAN granules with particular reference to their surface moisture zone.

## Experimental

Samples used for this investigation were same as used by the authors previously[2]. Of these, samples I and II were collected from the Nangal Unit of FCI Ltd., and the rest from Rourkela Fertilizer Plant. Except samples II and V, all were coated with a coating agent.

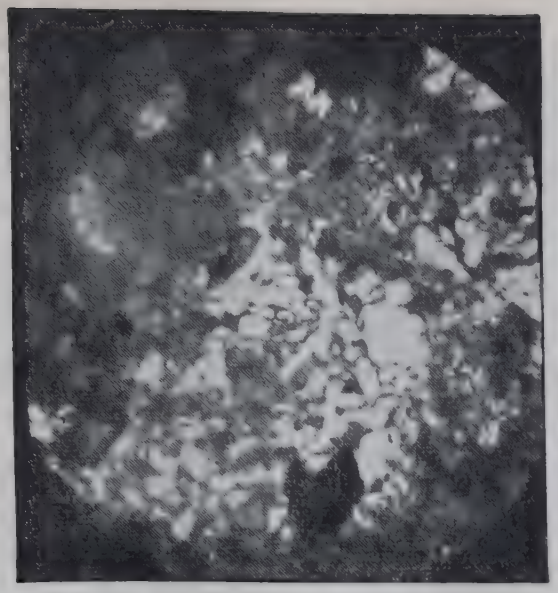
The core structure of the granules was examined by a microscope under transmitted light using a thin section of their granules. The procedure for preparing thin section has been reported by one of the present authors previously[4]. The section is cut through the centre of the granules. The photomicrographs are shown in Fig. 1.

The shape and size of the diluent particles were examined by a microscope under transmitted light with a magnification of 600x. The photomicrographs are shown in Fig. 2. The diluent particles were separated by treating 10 g. of each sample with 250 c.c. distilled water for 15 min. and finally filtered, washed several times and dried in oven at 100°C.

## Results and Discussion

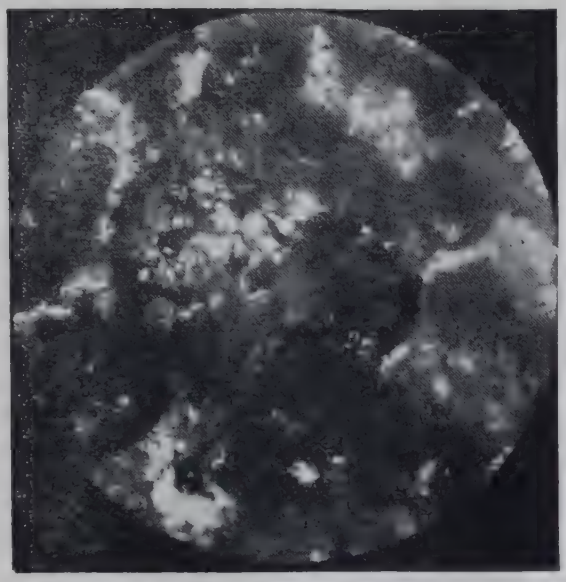
A closer examination of the core structure of the samples (Fig. 1) reveals that the distribution of ammonium nitrate particles inside the granules of sample IV (whose state of caking and surface moisture zone are found to be least of all[2]) is such that more ammonium nitrate particles occupy towards the centre than the surface end. Reverse is the case in sample III, whose caking is maximum of all the samples although its overall moisture content is found to be similar to that of sample IV[2]. The surface moisture zone arises because of the movement of saturated solution from the core towards the surface of the granules and the caking occurs in these zones due to subsequent recrystalliza-

Sample I

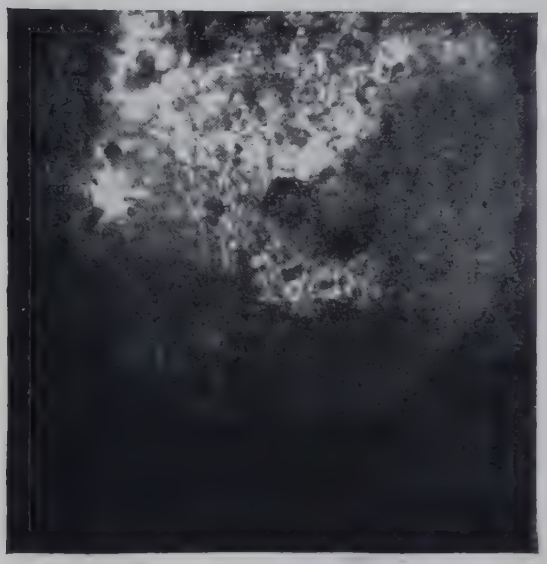


Sample II

Sample III



Sample IV



Sample V

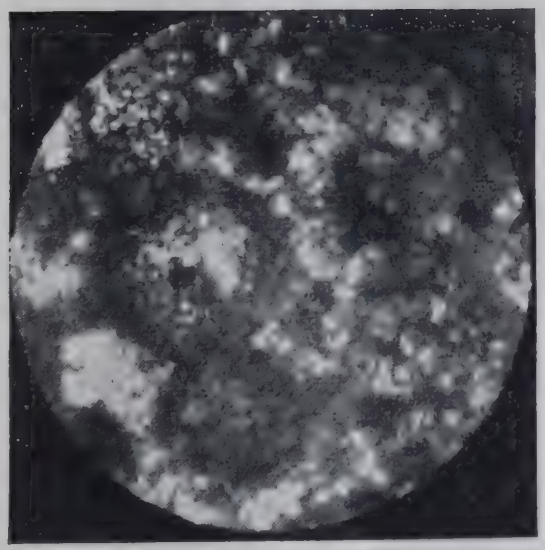


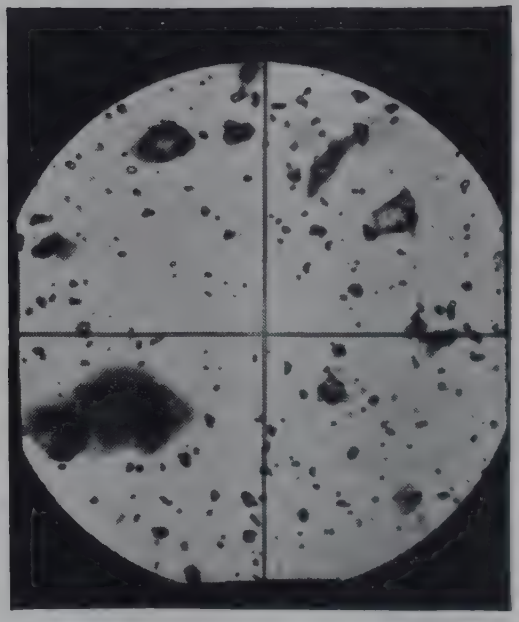
Fig. 1—Photomicrographs of Core Structure of CAN Granules. (×120)

Sample I

Sample II

Sample III

Sample IV



Sample V

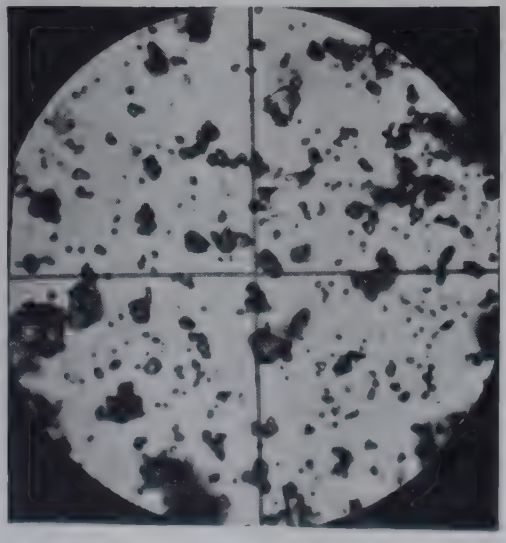


Fig. 2—Photomicrographs showing shape and size of Insoluble Particles of Different CAN Samples. (×600)

tion of ammonium nitrate as a result of which cementing of those granules takes place on these places. The greater the zone the more is the cementing and, therefore, the caking increases with increase of this surface moisture zone. The movement of the ammonium nitrate solution inside the granules causes the increase of internal pore size. Evidently, if the pore size is large the surface moisture zone is higher. An examination of their core structure indicates that this pore may increase in size if the ammonium nitrate particles are more towards the surface end than the centre of the granules.

It is interesting to mention here that the surface moisture zones of samples I and IV are similar to each other although their overall moisture content and core structure are different. In sample IV whose moisture content is much higher than that of sample I[2], more of the ammonium nitrate particles occupy towards the centre than in the case of sample I. Its pore size will, therefore, be smaller which prohibits movement of larger quantity of solution inside the core.

Again when the core structure of samples II and V is compared between themselves, it is observed (Fig. 1) that the distribution of ammonium nitrate particles inside their granules are similar. Their overall moisture content has also been found to be almost identical but the surface moisture zone of sample II is bigger than that of sample V[2]. This can be explained on the basis of the variation of the size of diluent particles. In fact the photomicrograph of their diluent particles (Fig. 2) reveals that their shape and size are different and the particles of sample II are coarser than those of sample V. It may also be mentioned here that these particles are found to be finer in samples whose surface moisture zone is less.

**Acknowledgements**

Thanks are due to Dr. K. R. Chakravorty, General Manager, Planning and Development Division, for his keen interest in this work. The authors' thanks are also due to Dr. S. Varma of the same Division for his valuable suggestions and to Dr. B. K. Banerjee and Sri K. C. Banerjee of the Physical Research Wing for their active encouragement.

REFERENCES

1. Silvorberg. J. J., Lehr, R., and Hoffmeister, G., *Agri. and Food. Chem.*, **6** (1958), 442
2. Mukherjee, S., Samaddar, M., and Roy, H., *Technol*, **2** (1965), 7
3. Delfosse, P., *Fertilizer and Feeding Stuffs, J.*, **45** (1956), 333
4. Samaddar, M., *Technol*, **2** (1965), 103

# Phosphoric Acid by Wet Process with Special Reference to the Process Developed by FCI Ltd.*

By

R. CHAMPATI AND B. B. ROY,

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

The production of phosphoric acid by the wet process is one of the most important intermediate steps in the manufacture of phosphatic fertilizers. This Division, has developed its own know-how based on pilot plant studies. In this article, the authors describe the general features of the FCI process and also indicate the planning for constructing a phosphoric acid plant based on the same. Basically, the FCI process reactor is a multicompartment unit producing gypsum in the form of dihydrate. They have also discussed other wet processes of phosphoric acid manufacture.

Phosphoric acid produced by the wet process is one of the most important basic materials for the manufacture of concentrated water-soluble phosphatic fertilizers. It is also produced by the furnace process, which gives a very pure product; and this is used mainly in chemical and food industries.

Till 1950 the bulk of phosphatic fertilizers was produced in the form of a low nutrient (16 per cent $P_2O_5$) single superphosphate. Since then there has been a shift towards the production of high analysis fertilizers which are mainly ammonium phosphate, triple superphosphate, etc.; in case of ammonium phosphate all the $P_2O_5$ is supplied through phosphoric acid, whereas in triple superphosphate 70 per cent of $P_2O_5$ is supplied through phosphoric acid. The direct application of phosphoric acid into the soil is also being practised in U.S.A.

At present the total capacity of phosphoric acid installed in India is about 0.20 million te/year of $P_2O_5$. The production planned by the end of Fourth Plan is 1 million te/yr. of $P_2O_5$.

* Paper read at the Seminar on Fertilizer Plant Engineering in India, held under the auspices of the Calcutta Regional Centre of the Indian Institute of Chemical Engineers at Calcutta, December 16, 1967

## Basic Process

The process involves the interaction of rock phosphate and sulphuric acid under controlled conditions for the production of a phosphoric acid-gypsum slurry having good filterability and good cake-washing property. During the reaction in the first phase, the rock dissolves into the acid and then crystallizes out in the form of gypsum having rhombic-shaped crystals, twins and clusters. The production of properly sized and shaped crystals is the most important feature in the wet process, and it requires special technique for obtaining economical extraction having good filterability. The reaction slurry is filtered in special filter units. The filtered acid is further concentrated, for utilizing in the fertilizer plants i.e. ammonium phosphate, triple superphosphate, etc.

## Reaction

At present two distinct processes are used in the commercial plants, viz. (i) Dihydrate process, (ii) Hemihydrate process.

*Dihyrate Process:* In this process the reaction and crystallization of gypsum is carried out at about 70-75°C. The heat of reaction is removed either by injecting air into the reactor or recirculating a part of the finished slurry through a vacuum cooler to the

reaction unit. The reactors may be either multi- or single-tank type. In the multi-tank system either a number of vessels or a tank divided into several compartments—each provided with a mechanical agitator—are used in series. The ground rock is generally fed through a poidometer to a premixer from where it goes to the first vessel or compartment of the reaction unit. The weak acid from the filtration unit (i.e. the acid after first wash) and the cooled recirculation slurry from the vacuum cooler are also fed to the premixer. Sulphuric acid of strength 98 to 65 per cent is fed into the second vessel or compartment through a flow meter. In some processes strong acid is diluted to 65 per cent, cooled and then used in reaction units while in others it is used directly.

The slurry flows by gravity. From the last tank or compartment, after completion of reaction and crystallization, the finished slurry is pumped into the filtration unit. A part of this slurry is recirculated through the vacuum cooler to the first vessel where the temperature of the reaction is controlled. This also controls supersaturation and helps in the proper growth of the gypsum crystals.

In the single tank system, the process followed is more or less the same as in multi-tank, but the construction of the reactor differs. In the single tank process one single cylindrical reactor is used, with an inner concentric tank. Several agitators provided in the annular space give the advantage of stage agitation and high recirculation which can be controlled by providing partial and adjustable baffles.

*Hemihydrate Process:* This process is characterized by the higher reaction temperature and consequently greater reaction speed that in the dihydrate process. The temperature used in the reaction stage is about 90-95°C. The whole reaction unit involves two steps, viz. decomposition and hydration. In the decomposition unit rock phosphate and sulphuric acid are reacted, in presence of the recirculating weak acid from the filter unit. At this stage. calcium sulphate precipitates out as $CaSO_4 . \frac{1}{2} H_2O$.

In the hydration stage, the hemihydrate formed in the decomposition stage is converted to dihydrate. The conversion is carried out under controlled conditions of temperature and slurry recirculation. At this stage the seed gypsum which is continuously produced in a separate unit under controlled conditions of temperature and consistency is added to accelerate the growth of crystals. This addition results in producing very stabilized and large size crystals having very good filterability.

**Filtration**

The slurry produced in the reaction unit is filtered normally in a horizontal tilting pan-filter, or other similar type units, where the gypsum cake is subjected to 2 or 3 stages of counter-current washing. Filtered product acid strength is about 28-32 per cent $P_2O_5$, depending on the type of rock used. As already indicated, the first wash (22 per cent $P_2O_5$ in case of 3-stage washing, and 17 per cent $P_2O_5$ in case of 2-stage) is recycled to the reaction unit. The final wash is carried out with hot water for the maximum removal of $P_2O_5$ from the gypsum cake.

**Concentration**

The acid produced in the filtration unit normally cannot be used directly in the finished fertilizer processing plants. In ammonium phosphate and granular TSP production about 45 per cent $P_2O_5$ acid is used, whereas in case of powdered TSP production about 50-52 per cent $P_2O_5$ acid is used. The following two are the main processes adopted for concentration of the acid viz. submerged combustion, and vacuum evaporation with steam heating.

In the submerged combustion, the fuel gas and air mixture is introduced under the acid and ignited. The hot gas bubbles through the acid thereby concentrating the latter. This type is not widely used now-a-days because of heavy $P_2O_5$ losses.

The vacuum evaporators used are single-effect forced-circulation type with external calandria, using either steam ejectors or vacuum pumps for maintaining the vacuum. Low pressure steam (1 kg./cm²g. or even below) is used as the heating medium to maintain minimum temperature differential across the heating surface, which results in less scaling in the heater tubes.

**Storage**

The product acid from the filtration unit contains a considerable amount of suspended solids. Some gypsum particles always leak through the filters. Moreover, during evaporation calcium sulphate and fluosilicates precipitate due to decreased solubility. The acid is therefore to be freed from these suspended matters before using in the finished product plants to avoid dilution and the serious scaling of the pipe lines. Sufficient time is allowed to the product acid in the storage

tank to settle the suspended solids, and the thickener mechanism provided to these tanks makes the settled matter move to a discharge point. Reagents like starch and separan may also be added to the acid for quick settling of the suspended matters.

### Materials of Construction

In modern practice, the reactors are made up of mild steel. The sides and bottom of the reactor are provided with rubber-lined acid-proof bricks and finally carbon bricks of suitable thickness. The top cover is lined only with rubber, which may be either natural or synthetic like SBR Nitrile, butyl or neoprene. The agitators are generally of special alloy steel, though rubber-lined mild steel construction is also used.

For the filter, normally A.I.S.I. 316** L.C. is used, but recently some of the maunfactures are going A.I.S.I. 317** L.C. which is calimed to be superior to the former but costlier.

The evaporator unit is generally made of mild steel shell lined with special rubber of both hard and soft variety. Special alloys of high-nickel high-chromium can also be used. But this becomes very costly.

The storage tanks are generally made of mild steel with inside rubber-lined. Some designers use acid-proof brick lining in the bottom to save rubber-lining from direct abrasion due to the suspended solids in the acid.

For the pumps since long A.I.S.I. 316 was used, but its life is very short. The best choice is hastealloy C, which gives quite a good life but it is very costly. Rubber-lined pumps have also been tried, but not found satisfactory due to abrasive characteristics of of the material. Now-a-days special high-nickel, high-chromium alloys i.e. HV9A (Belgium standard), alloy 20 etc. are normally used.

Rubber-lined mild steel is normally used for the bigger size pipes, reinforced hose also can be used. In modern practice, glass-fibre-reinforced plastic pipings are used upto a size of 200 mm., which give a better life than the rubber-lined ones.

### Salient Features and Economics of Various Processes

#### Reaction

*General:* The design of the reaction unit is the vital part in the phosphoric acid plant. The production of suitable quality gypsum crystals having good filterability is the main purpose. The direct reaction of the rock and sulphuric acid is undesirable because it may form a coating of insoluble calcium sulphate and thus block further reaction. And also in that case gypsum crystals formed may be too small to filter. Therefore, in most of the designs a premixer is usde for mixing the rock with the weak acid received from filtration unit and the recirculating slurry.

Another object of premixing is to keep the $Ca^{2+}$ and $SO_4^{2-}$ concentrations low in the slurry so as to get controlled crystallization of the gypsum. In some plants the strong sulphuric acid is premixed with weak circulating acids or with the recirculating slurry for rapid dispersal of the acid. In reactors, the liquid phase (slurry) consists mainly of phosphoric acid with a small percentage of free sulphuric acid, while the solid phase is mainly gypsum with a small amount of unreacted rock. This condition helps the phosphate rock to react first with phosphoric acid in the slurry to form monocalcium phosphate, which in turn reacts with sulphuric acid producing phosphoric acid and calcium sulphate. Since the calcium sulphate is formed in the solution phase, with supersaturation, it crystallizes. The size and shape of the crystals depend very much on the degree and uniformity of supersaturation.

The agitators are of shrouded impellor-type with double-impellor system in a single shaft. The intensity of agitation varies in different vessels or compartments. In the premixer where the rock is added the highest intensity of agitation has to be maintained. The intensity of agitation depends very much on the type of rock.

Recirculation of slurry is another important feature in designing. In the multi-tank system a submerged pump conveys the slurry to the vacuum cooler from where it is circulated to the point where rock is added. The control of recirculation is made through a distributor from where the excess slurry can be fed back to the last compartment. This is an essential criterion in the design to take care of the different varieties of rock. Normally the circulation is maintained at about 10-15 times the feed, but with some rock it may go up to 40 times also. In case of uncertainties of the quality of rock this flexibility, though very costly, has to be provided in the design.

To complete the growth of the crystals, normal retention time varies from 3 to 8 hours depending upon the design and quality of the rock used. But considering the recirculation of the slurry the net detention time is 25-45 minutes only. In case of a multi-tank

** Types of stainless steel standardized by the American Iron & Steel Institute.

system using a difficult rock phosphate more circulation is better. This, of course, increases the cost considerably due to high capacity circulation pumps, larger size of pipes, valves, etc. But the higher recirculation rate minimizes the citrate-soluble $P_2O_5$ loss, i.e. $P_2O_5$ which is lost as dicalcium phosphate. This is because higher recirculation reduces the amount of co-precipitation of dicalcium phosphate in the gypsum lattice, and also a higher recirculation maintains a higher average sulphate level in the reaction system which minimizes the $P_2O_5$ loss becasue the amount of citrate-soluble $P_2O_5$ is in inverse proportion to the excess sulphuric acid present in the system. Of course, with too high a recirculation, there is always the chance of short-circuiting.

Another important factor in the disign is the amount of free sulphuric acid to be maintained in the liquid phase of the reaction system. The optimum value depends mainly on the type of rock used, and to a certain extent on the design of the reaction unit. In most of the plants using Florida rock, the optimum limit is within the range of 1.5-3 per cent sulphuric acid. Decreasing the acid concentration below this optimum value results in the formation of small crystals, having poor filterability, while increasing the concentration higher than 3.0 per cent produces needle-like crystals which results in poor filtration rates. Also it enhances the corrosion in various subsequent equipment.

*Multiple vs. Single Tank Reactor:* The multi-tank system is far superior from the standpoint of flexibility and assured continuity of operation. For smaller size plants it is a little costlier but for larger plants in this system the cost savings is effected by a single large tank, compared to a multi-tank unit. The costly system of slurry recirculation by a pump is avoided in this process. The agitators and the adjustable baffles in the annular space are so designed that the desired amount of recirculation is maintainted. But a disadvantage in this system is that it is difficult to avoid short-circulating and the unit is less flexible and cannot run efficiently at low load. Moreover, there is a limit in making a single unit for a very high capacity plant more than a 325 te/day of $P_2O_5$ unit is not possible. The stream efficiency also is comparatively low with this system.

*Dihydrate vs. Hemihydrate Process:* The dihydrate process is the standard commercial practice. Many plants have been installed all over the world using this process, with various capacities ranging from 20 to 450 $P_2O_5$/day. The biggest plant installed by M/s Wellman-Lord Engineering in U.S.A. is having a capacity of 900 te $P_2O_5$/day. It is laid in two identical streams.

The hemihydrate process has been put into commercial practice only very recently. Till now no large-scale plant has been designed on this process. The biggest plant so far installed using Nissan process is having a capacity of 200 te $P_2O_5$/day, and M/s N. K. K. of Japan has not so far built any plant with a capacity more than 100 te $P_2O_5$/day. In this process, extraction efficiency is very high due to high temperature causing more defluorination which thus yields acid and by-product gypsum of lower fluorine content. $P_2O_5$ extraction efficiency in this process is about 98.5-99 per cent compared with about 96 per cent with dithydrate process. The by-product gypsum produced contains fluorine and $P_2O_5$ of the order of 0.3 and 0.25 per cent for the N. K. K. process and 0.32 and 0.7 per cent respectively for the Nissan process, compared to 1.0 and 1.2 per cent respectively in the dihydrate process. The hemihydrate process has its special importance and advantage where the by-product gypsum of very high quality is desired.

But due to higher temperature maintained, there are the chances of more corrosion in the reactor units. Another disadvantage is that large capacity plants cannot be installed in a single stream. The maximum capacity to which a plant in a single stream can be laid is 200 te.$P_2O_5$/day.

As regards the capital investment there is not much of difference between the two processes. Of course, for the higher capacity plants where sigle-stream unit cannot be installed for the hemihydrate process, dihydrate becomes cheaper.

**Filtration**

In a phosphoric acid manufacturing plant, continuous washing and reconditioning of cloth and supporting parts of filter for efficeint operation are of basic necessity. And during the last few years many modifications have been incorporated to the filters to fulfil this basic need. There are at present three types of filters normally in use commercially viz. (a) travelling pan (Giorgini) of Dorr-Oliver Companies; tilting pan filters of (b) E.I.C. Belgium & (c) Eimco Corporation, U.S.A. Though differing mechanically they are functionally identical. The following are their three special features.

(i) *Washing of Cloth:* The solution, supersaturated with gypsum and fluosilicates, has a tendency to precipitate and form scales on the cloth sufraces, and pores. In case of the tilting and travelling pan filters where the filler cloth and pans are in an inverted position washing them thoroughly with fresh water at every cycle is a recently evolved technique. In the Ucego filter also a thorough wash is possible due to the special feature of the rim band at the outer circumference.

(ii) *Cake Washing:* During cake washing it is possible to flood the surface of the cake with wash solution or water, which is then sucked through the cake. This is an ideal arrangement from the standpoint of obtaining true displacement washing. No sprays of wipers are required. These filter units are very much similar to a laboratory-operated Buchner funnel type-testing unit. So the expected performance of a pan filter for a particular slurry can be very accurately predicted from simple tests.

(iii) *Cake Discharge:* The ability to discharge the gypsum cake completely and clearly when the pans are in tilted or vertical position is a great advantage with the tilting and travelling pan filters. In Ucego filter an endless screw removes the washed cake. This filter is provided at the outer circumference with an endless rim band of rubber, held in position by tensioning rollers. The outstanding feature of this rim band is that it moves away from the outer edge of the table at the point where the cake is removed, thereby enabling a thorough washing of the filter cloth.

(iv) *Economics:* The travelling pan filters are generally in small sizes, say upto 20 $M^2$ effective surface or so, and for small size plants they are economical but their maintenance cost is generally higher than that of the tilting pan and Ucego filters. In recent days the tilting pan and Ucego filters are available in bigger sizes, viz. upto a maximum size of 120 $M^2$ effective surface. But for higher capacity, it is always preferable and cheaper to have one tilting pan instead of 2 or 3 travelling pan filters. Regarding the relative economics of the tilting pan and Ucego filter sufficient data are not available.

(v) *Filter Fabrics:* Polythene fabrics with mono-filament texture are generally used in modern plants. In the travelling pan filter the life of such fabrics is about 5000-6000 hours whereas in tilting pan it is somewhat less.

**Concentration**

As already indicated, there are mainly two methods of concentration, viz. (i) submerged combustion, (ii) vacuum evaporation.

Submerged combustion offers simplicity and high economy, but the problems like removal of mist and fumes by ordinary scrubbling and finding a suitable material of construction for the burner are its main drawbacks. Higher loss of $P_2O_5$ is also a problem in this type.

A forced circulation single-effect vacuum evaporator, using low pressure steam as a heating medium, is widely used in the industry. The multiple-effect evaporators cannot be used because of too high boiling point elevation and fouling of heat exchangers due to the evolution of $SiF_4$. The main advantage of this type over the other process is the complete elimination of fumes problem and negligible loss of $P_2O_5$.

The evaporators generally operate with 700 mm. Hg vacuum, inside and maximum temperature of about 85°C. Normally a single unit of this type is made for a maximum capacity of about 120-150 te $P_2O_5$/day, when the acid is to be concentrated upto 54 per cent $P_2O_5$. In case of bigger capacity plants, 2 or 3 identical units are installed in series, each one working as a single-effect unit.

**Know-How of the Processes**

The following are the firms possessing the know-how of the dihydrate process: (i) M/s Dorr Oliver, U.S.A.; (ii) M/s U.C. B-P.S.G. Belgium-France; (iii) M/s Chemico, U.S.A.; (iv) M/s E.I.C. S.A., Belgium; and (v) M/s FCI Ltd. India.

The E.I.C. and Chemico processes are based on multi-tank reaction principle with a vacuum cooling device. The Dorr Oliver & U.C.B-P.S.G. processes operate on single-tank reaction system with air cooling. FCI process is based on multi-tank reaction system with vacuum cooling device.

The know-how of the hemihydrate process is possessed by (a) M/s Nissan Chamicals, and (b) M/s N. K. K., of Japan. The two processes are almost identical, except that in the latter the by-product gypsum obtained contains lesser amount of fluorine. Active silica is added in the reaction unit which combines with fluorine in the rock forming silicon tetrafluoride escaping with the vapour.

*Import of Know-How:* Amongst the several plants already installed in India, some have adopted the imported know-how, as indicated below.

| Plant | Location | Capacity $P_2O_5$/yr. | Know-how supplied by |
|---|---|---|---|
| FACT | Alwaye | 9240 | M/s. E.I.C. |
| -do- | -do- | 27000 | M/s. Dorr Oliver |
| EID Parry | Ennore | 10500 | M/s. E.I.C. |
| C.S.I.C. Ltd. | Gujarat | 49920 | M/s. Chemico |
| Coromandel Fertilizers Ltd. | Visakhapatnam | 73000 | M/s. Dorr Oliver |
| Dharamsi Morarji Chemical Co. Ltd. | Ambarnath | 7200 | |

(M/s Fertilizers and Chemicals of Travancore Ltd. (FACT) have entered recently into a licence agreement with M/s E.I.C. of Belgium for the supply of their process know-how. This agreement is awaiting the approval of the Government of India.)

*Status of Indigenous Know-how:* The Planning and Development Division of FCI Ltd. is now in a position to design and engineer phosphoric acid plants up to a capacity of 100 te/day of $P_2O_5$, based completely on their own know-how. Already an offer is given to a state government undertaking to set up a plant (85 te/day of $P_2O_5$ capacity) as a part of their fertilizer complex. Design for another plant (100 te/day of $P_2O_5$) for one of the FCI Units has also been initiated. The design for both the plants has been taken up without any imported technical assistance.

The know-how for a large size single-stream plant in India is still to be imported. P&D Division is building up a semi-commercial plant to develop the know-how for a larger size commercial plant in a single-stream unit. It is expected that the study will be completed within next two years and subsequently the design of a larger plant also can be taken up by this Division on the basis of its own know-how.

Regarding the engineering for these plants this Division has already developed its full facilities. There are a few private organizations like Krebs India Ltd., Dorr Oliver India and Simon Carves India, who can undertake the design and engineering of such plants based on their foreign principal's know-how. It is, therefore, simple to assume that the future large capacity plants could be executed by Indian organisations importing only the basic know-how from abroad wherever necessary.

*Typical Design Features of FCI Process:* The salient features of this Division's process are (i) direct use of 93 to 98 per cent sulphuric acid without any prior dilution, thereby saving the investment and operating costs of the acid dilution system; (ii) control of reaction temperature by cooling a part of the recirculating slurry under vacuum; (iii) entire quantity of process water input to the plant is introduced as wash water in the filter, thereby ensuring maximum extraction of $P_2O_5$ from the gypsum cake without affecting the concentration of the filtered acid; (iv) use of two-stage washing system in the filter instead of the conventional three-stage washing, meaning thereby reduced size of the filter and more effective washing of gypsum cake; (v) outdoor installation of the reactor unit, thus making a saving in civil works cost; (vi) better control of reaction conditions due to use of multi-compartment rectangular reactor; (vii) production of rhombic crystals of dihydrate gypsum having good filtration characteristics; and (viii) the quality of gypsum is suitable for the production of ammonium sulphate.

The reactor is a single rectangular tank divided into eight compartments of equal size (Fig,1). Each compartment is provided with a variable speed turbine type agitator of special design. The speed can be adjusted to control the intensity of agitation for different rock phosphate from different sources. The ground rock with a fineness of 100 mesh (Tyler) is fed into the first compartment where the slurry from the last compart- is recirculated after cooling. This helps in removing the heat of reaction as well as in maintaining a proper concentration of sulphuric acid in the reaction mass. The pump used for the recirculation of slurry is a vertical submerged-type of special chrome-nickel steel to withstand both corrosion and erosion of the slurry. The slurry flows by gravity from one compartment to another through a specially designed weir placed alternately at the bottom and top of different compartments. A mixture of fresh sulphuric acid and weak circulating acid from the filter is added to the second compartment after mixing in a specially designed mixer. The temperature maintained in each of the compartments is between 70-72°C. The free sulphuric acid content of the slurry is adjusted between 2.5 to 3.0 per cent which influences greatly the quality of gypsum crystals produced. Provision is also made for recirculating a part of the product acid from the filter to the reactor if the rock phosphate with a low $P_2O_5$ content is used.

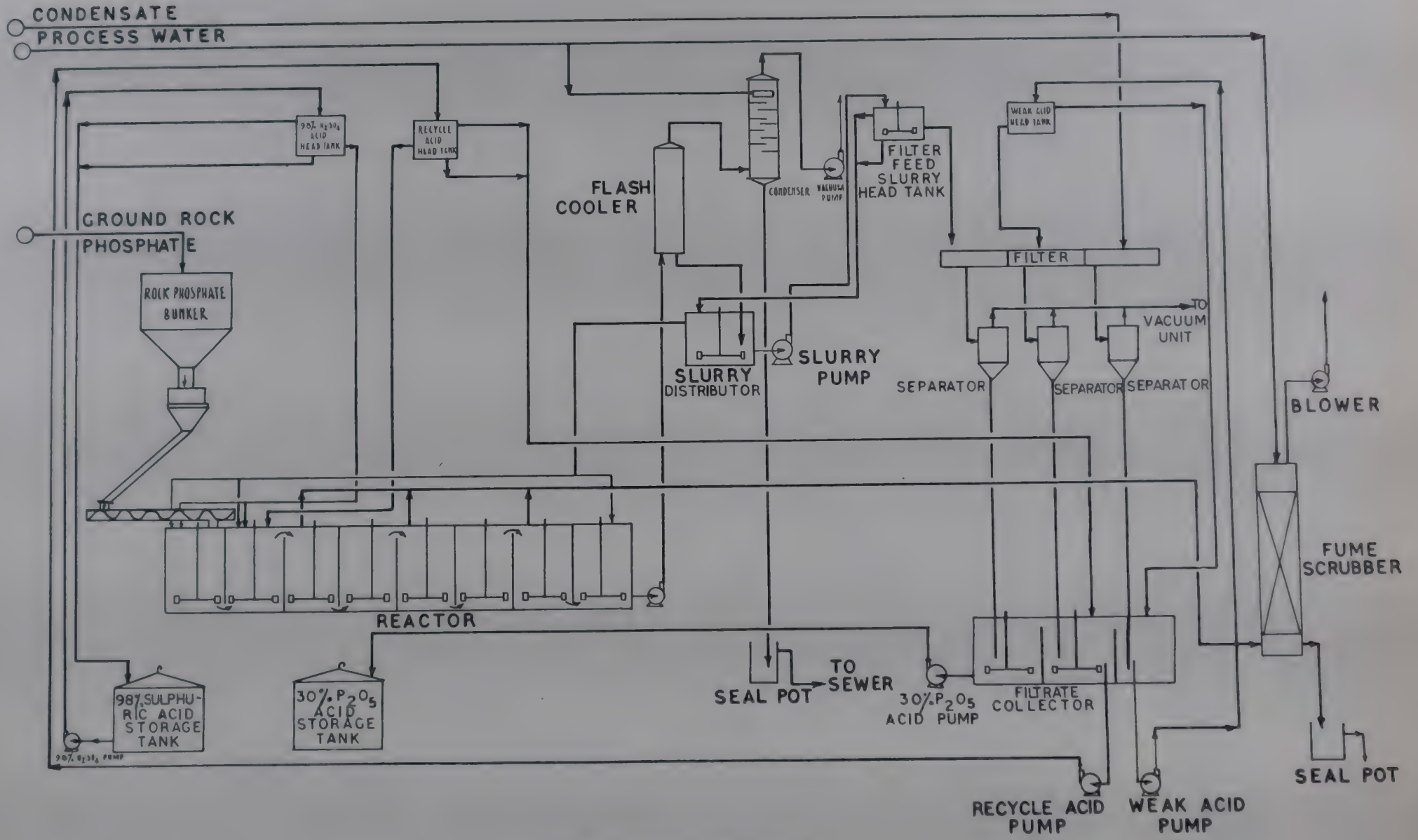



Fig. 1—Process Flow Scheme.

TABLE 1—Typical Operating Data of the FCI Process

TABLE 1A—Reaction

| | Acid Strength, % $P_2O_5$ by weight (after filtration) | Analysis of Filtered & Washed By-product Gypsum (dry basis) | | | Average Size Analysis of Gypsum Produced | Average Efficiency of $P_2O_5$ Converted (reaction filtration combined) | Remarks |
|---|---|---|---|---|---|---|---|
| | | % fluorine | % Sol. $P_2O_5$ | % in-Sol. $P_2O_5$ | | | |
| (i) | 31.8 | 0.75 | 0.30 | 0.80 | 14% +100 mesh<br>38% +150 mesh | 96.5% | Filtration and washing was carried out in Lab. type buchner funnel filter unit under commercial plant operating conditions. |
| (ii) | 30.9 | 0.62 | 0.41 | 0.51 | -do- | 96.0% | |
| (iii) | 31.5 | 0.83 | 0.34 | 0.75 | -do- | 95.8% | |

TABLE 1B—Filtration

| | |
|---|---|
| Type of test | : Laboratory Buchner funnel |
| Diam. of Buchner funnel | : 300 mm. |
| Cake thickness | : 50-60 mm. |
| Type of filter cloth | : Polythene composed of 100% monofilament fabrics. |
| Vacuum applied at the filter end | : 350 mm. Hg. |
| Temperature of slurry | : 70°C. |
| Slurry specific gravity | : 1.55-1.60 |
| Slurry viscosity | : 200-250 c.p. approx. |
| Rate of slurry filtration | : 4.5-5.8 $m^3$/hr./$m^2$ |
| Moisture in the gypsum cake | : 22-25% |
| Temperature of wash water used | : 70°C. |
| Amount of wash water used | : 5.5 $m^3$/te. $P_2O_5$ |
| No. of stages of washing | : 2 |

The reaction volume to be provided depends to a large extent on the quality of rock phosphate. Normally with rock from Florida, Jordan, or Morocco, the reaction volume varies from 2.5 to 3.0 $M^3$/te of $P_2O_5$/day production. Foaming is usually controlled by anti-foaming agents. The typical operating data for the FCI process are given in the following table [Tables 1 (A & B)] based on a series of test runs carried out on pilot plant scale with Jordan rock phosphate.

# Infrared Study of Apatite Mineral

In connexion with the recent observations on phosphate absorption bands and symmetry of carbonate ion in the apatite structure made by Bhatnagar[1], we would like to clarify certain points regarding the same. Bhatnagar has stated that according to the group theory, the three bands for $\nu_3$ vibration of $PO^{3-}_4$ and three bands for $\nu_4$ of $PO_4^{3-}$ is expected. Further, according to him in carbonatoapatite, the symmetry of the carbonate ion is reduced from $D_{3h}$ to $C_{2v}$.

Regarding, the phosphate bands we have also observed[2] three bands for $\nu_4$ vibration but only two bands for $\nu_3$ vibration. For normally tetrahedral molecules having a modified symmetry, resolution of latent $\nu_1$ mode is accompanied by removal of the degeneracies of $\nu_3$ so that either two or three absorption bands would be apparent for the latter mode. In some cases, however, the split bands may not be resolved and even a single $\nu_3$ band may appear. In fact, Romo[3] has also observed only two bands viz. 1045 $cm^{-1}$ and 1090 $cm^{-1}$ for this mode. Although we have assumed $C_{3v}$ symmetry for $PO_4^{3-}$ ion in apatite, but because of the possibility of the unresolved bands and unrevealed degeneracies, it was clearly stated in our earlier communication[2] that phosphate ion in apatite can also have $C_{2v}$ or $C_s$ symmetry. Considering the bond length data for the $PO_4$ group in apatite by Posner[4] et al, $C_s$ molecular symmetry appears most reasonable. It is possible, therefore, that one cannot unambiguously draw a conclusion as to the exact molecular symmetry of the pohsphate ion in apatite from the infrared data. Nevertheless, it should be clear that the molecule would have no higher symmetry than $C_{3v}$ considering the molecular dipole indicated by the presence of at 959-964 $cm^{-1}$.

Bhatnagar has concluded that symmetry of carbonate ion in apatite is reduced from $D_{3h}$ to $C_{2v}$. The reasons for not believing in the degradation of $D_{3h}$ symmetry to $C_{2v}$ are that in order to have a $C_{2v}$ symmetry, the selection rule must differ as is shown in the following character table.

TABLE 1

CORRELATION BETWEEN $D_{3h}$, $D_3$ AND $C_{2v}$

| Point Group | Number of Infra-red Active Vibration | | | |
|---|---|---|---|---|
| | $\upsilon_1$ | $\nu_2$ | $\nu_3$ | $\nu_4$ |
| $D_{3h}$ | 0 | 1 | 1 | 1 |
| $D_3$ | 0 | 1 | 1 | 1 |
| $C_{2v}$ | 1 | 1 | 3 | 3 |

It can be seen from the above character table that in $C_{2v}$ symmetry, $\nu_1$ vibration (symmetric stretching mode) which is forbidden in the free ion become infrared active and each of the doubly degenerate vibrations, $\nu_3$ (an asymmetric stretching) and $\nu_4$ (planar bending) splits into three bands. The appearence of $\nu_1$ mode is of considerable interest because it suggests a distortion in the symmetry of the internal oscillation which may reflect the asymmetry in the $CO_3^{2-}$ ion. In addition to this, we will expect a displacement of out of plane bending mode ($\upsilon_4$) to lower frequencies and stretching mode ($\nu_3$) to higher frequencies. As discussed in our earlier communication[2] that neither $\nu_1$ mode is present nor there is splitting of $\nu_4$ (which is absent in all the apatite examined except in one variety where one band is present). Hence, by observing only splitting of $\nu_3$ band (the magnitufe of which is not much as compared to aragonite and other carbonato complexes having $C_s$ and $C_{2v}$ symmetry respectively), it will be wrong to arrive at the conclusion that the symmetry of the carbonate ion is $C_{2v}$ in the apatite structure. We have explained this anomalous situation in our earlier communication[2] on the basis of the findings by Nakamoto[5]

*A Letter by Dr. V. M. Bhatnagar appeared in the last issue of TECHNOLOGY, viz. Vol. 4 (4) (1967), 148, making some observations on the studies made by Sarbasri A. K. Chakravorty and S. K. Ghosh on 'Infra-red Spectra of Apatite Mineral TECHNOL, 3 (1966), 148. A reply to Dr. Bhatnagar's observations is given by the authors in this letter.—*Editor.*

on the carbonato amine complexes. Their observation is shown in Table 2.

TABLE 2

| | Symmetry | $\nu_1$ | $\nu_2$ | $\nu_3$ | $\nu_4$ |
|---|---|---|---|---|---|
| Free $CO_3^{2-}$ ion | $D_{3h}$ | | 879 | 1415 | 680 |
| Calcite | $D_3$ | | 874 | 1430 | 710 |
| Aragonite | $C_s$ | 1080 | 855 | 1470 | 710 |
| | | | | | 696 |
| $[Co(NH_3)_6]$ $ClCO_3$ | $D_3$ | | 868 | 1390 | 688 |
| | | | | 1370 | |
| $[Co(NH_3)_4$ $CO_3]Cl$ | $C_{2v}$ | 1025 | 837 | 1592 | 752 |
| | | | | 1255 | |

It can be seen from the above table that when carbonato ion is in the outer sphere of the complex, $\nu_3$ splits while maintaining the same symmetry as that of calcite and when this ion is inside the coordination sphere, the symmetry is changed and the splitting of the degenerate mode is larger. This splitting of $\nu_3$ may be due to the perturbation caused by the crystal field. On the basis of the explanation offered by Nakamoto[5], it seems quite reasonable to assume the similar behaviour of carbonate ion in apatite structure. In the opinion of the authors, Bhatnagar's explanation regarding the splitting of $\nu_3$ band is not very convincing.

A. K. Chakravorty and S. K. Ghosh,
Planning & Development Division, Fertilizer Corporation of India Ltd., Sindri, Bihar

REFERENCES

1. Bhatnagar, V. M., *Technol.*, **4** (1967), 148.
2. Chakravorty, A. K. and Ghosh, S. K., *ibid* **3** (1966), 148.
3. Romo, L. A., *J. Amer. Chem., Soc.*, **76** (1954), 3924.
4. Posner, A. S., Perloff, A. and Diorio, A. F., *Acta Cryst.*, **11** (1958), 308.
5. Nakamoto, K., *J. Amer. Chem. Soc.*, **79** (1957), 4904.

# Notes & News

### Synthesis Gas from Talcher Coals*

In order to study the gasification characteristics of −25 mm. Talcher (Orissa) bottom seam coal for the production of synthesis gas in both the atmospheric and high pressures, tests were carried out in the pilot plants of the Central Fuel Research Institute.

*Tests in Koppers-Totzek Plant (Atmospheric Pressure)*: Experiments were carried out under different operating conditions using coal having fineness of 80 per cent through 200 mesh (BSS). The moisture of the raw coal which was about 10 per cent prior to conducting gasification tests was reduced to about 5 per cent by hot-flue gas drying. The hourly coal feed rate was about 91 kg. The results from five tests indicated that for economic synthesis gas generation with coal ground to 30 per cent through 200 mesh (BSS), it may be profitable to operate the gasifier with 0.5021 $Nm^3$. of oxygen and 0.24 kg. of steam per kg. of coal. Under these conditions the requirements of raw materials for producing 1000 $Nm^3$. of synthesis gas ($CO+H_2$) will be about 802 kg. of coal and 402 $Nm^3$. of oxygen. The requirement of coal can, however, be reduced considerably by recycling back into the gasifier the high carbon rejects collected in cyclone. The percentage of carbon gasified was 76.8 and the thermal efficiency was 60.0 per cent.

Two more tests were also carried out using coal having fineness of 90 per cent through 200 mesh (BSS). The results showed that by employing 0.4932 $Nm^3$. of oxygen and 0.21 kg. of steam per kg. of coal, the requirement of raw materials for producing 1000 $Nm^3$. of synthesis gas ($CO+H_2$) is only 767 kg. of coal and 378 $Nm^3$. of oxygen. Thermal efficiency and carbon efficiency were 62.4 and 79.5 per cent respectively.

The effect of steam-to-coal ratio on gasifier performance was also studied, maintaining nearly the same amount of oxygen (around 0.4939 $Nm^3$/kg. of coal), but varying the steam/coal ratio from 0.21 to 0.47. The $CO/H_2$ ratio in the product gas could be achieved by increasing the steam/coal ratio but only at the cost of efficiency figures and incurring larger consumption of raw materials.

The hydrogen sulphide and ammonia concentrations in the product gas were found to vary from 170 to 230 gm. and 5 to 6 g. respectively per 100 $Nm^3$. of the gas.

*Tests in Lurgi Pressure Gasification Plant*: Five tests, each of 8 hours' duration, conducted with Talcher coal (size 6-25 mm.) were carried out at operating pressures of gasifier ranging from 14 to 25 kg./$cm^2$. The percentage of carbon dioxide in the raw gas was maintained around 30 by suitable adjustment of steam/coal ratio (1.67-1.82) and varying the amount of oxygen from 0.272 to 0.284 $Nm^3$ per kg. of coal. The coal feed rate varied from 340 to 498 kg./hr. The calorific value and methane content of the raw gas varied from 2786 to 2944 kcal./$m^3$. and 9.7 to 11.7 per cent respectively, while the figures for thermal and carbon efficiencies were in the ranges of 68.6-74.4 per cent and 75.6-82.8 per cent respectively. The $H_2/CO$ ratio in the product gas varied from 2.18 to 2.72. The requirement of raw materials for producing 1000 $Nm^3$. of purified gas with a calorific value of 4176 kcal./$m^3$. was 804 kg. of coal, 1406 kg. of steam and 228 $Nm^3$. of oxygen, when the thermal efficiency of the plant was at its maximum, i.e. 74.4 per cent.

The concentrations of hydrogen sulphide, ammonia and nitric oxide in the raw gas prior to its entry to the hot potash unit were determined for some of the gas samples. These concentrations varied from 4 to 14 g. for ammonia and 325 to 550 g. for hydrogen sulphide per 100 $Nm^3$. of gas. The concentration of nitric oxide was estimated to be about 0.3 ppm.

The yield of tar was 57.5 l./ton of dry coal. About 89 per cent of the total tar yield was light tar while the rest constituted the heavy tar. The quality of tar and its composition and distillation characteristics were determined.

[*FRI News*, **16** (3) (1966), 88]

*Based on a Report of the Gasification Division, CFRI, Dhanbad.

### Urea for Recovering n-Paraffin from Petroleum Fractions

In urea adduct processes for n-paraffin recovery, crystalline urea or solutions of urea are used. n-Paraffins of more than five carbon atoms are occluded in the channels present in urea crystals.

Crystals of urea, oil and an activator are mixed with agitation during one process employing urea crystals. The solid adduct is filtered from the de-waxed oil on a rotary-drum, vacuum filter and is decomposed in a second vessel by part of the de-waxed oil at 230°F or by water at 170 to 185°F. The urea is separated from the oil either as a solid or as a solution which is evaporated to produce crystals for re-use. In Hungary, the feed is first treated with sulphuric acid and clay, the adduct is formed, is separated by a centrifuge, is washed with gasoline and is decomposed at 175°F by urea solution which is saturated at 70°F. The solution is separated from the wax, is cooled and the urea crystals so obtained are re-used. n-Paraffins may also be obtained by percolation of oil through a bed either of crystalline urea or of urea deposited on a carrier, the adduct is decomposed either by hot gases or by hot liquids, the paraffins are withdrawn, the bed of urea is washed for re-use.

Aqueous solutions of urea are used to de-wax solutions of oils in solvents, the solid adduct is separated either by filtration or by decantation, a rise in temperature of the dilute urea solution decomposes the adduct. n-Paraffins of $C_{10}$ and $C_{40}$ and above are produced by using a concentrated urea solution. Adducts from n-paraffins with low carbon numbers are unstable and the yields of such n-paraffins are lower than yields of n-paraffins of higher carbon numbers. The reaction of urea and n-paraffins in a distillate is in equilibrium which is a function of such variables as

temperature and the volume ratios of oil, solvent and urea in solution. Some solvents for oil, e.g. methylene chloride, and for urea, e.g., water, increase the reaction rate. The adduct is precipitated from solution as granular, small particles and the most desirable granulation is influenced by the oil solvent. The granules are filtered, washed and dried on a rotary pressure filter. The adduct is heated to 175°F and water is added to form a urea solution and n-paraffins which are separated. The residual oil has a low pour point. The granules are mixed with fresh solvent when products of high n-paraffins content are desired.

[*Brit. Chem. Engng*, **12** (3) (1967), 403]

**Fisons Hemihydrate Phosphoric Acid Process**

The success of the wet process lies in replacing calcium contained in a phosphate rock complex by hydrogen ions using acids stronger than phosphoric acid itself. The commercial application of the wet process has been almost entirely limited to the use of sulphuric acid. Depending on the temperature and acid concentrations in the reaction system the calcium sulphate may precipitate in the dihydrate, hemihydrate or anhydrous form. The methods by which satisfactory crystals of these forms are obtained and which will be filtered and washed economically are of importance.

Fisons Fertilizers Ltd. has developed a wet process for the manufacture of concentrated phosphoric acid of 55 per cent $P_2O_5$ based on hemihydrate with a single stage filtration.

From a kinetic point of view the dissolution of phosphate rock in the hemihydrate process presented no new problems over those normally found in the dihydrate process. Satisfactory crystal growth was studied in a multiple reaction system in which the variables affect the size of the crystal size such as precipitation, reactor sequence, recycle reaction temperature and mixing. The major $P_2O_5$ loss in wet process is that contained in the calcium sulphate lattice. In order to obtain good hemihydrate crystals it is necessary to some extent to operate under conditions which balance lattice $P_2O_5$ against filtration $P_2O_5$ losses. The efficiency of the process depends on $P_2O_5$ concentration of the acid produced. Under the correct operating conditions, the hemihydrate produced in this process in fast filtering can be washed economically.

The new Fisons hemihydrate process offers the following advantages to the manufacture of phosphoric acid: (1) The process is capable of producing acid of 50 per cent $P_2O_5$ concentration directly without the need for evaporation. (2) A coarse phosphate rock is processed and it is only necessary to grind material which will not pass a 1/16 in. screen. (3) The phosphoric acid produced has a lower sulphate and fluorine content than is usual with the dihydrate process. (4) The process is flexible in that acid of any concentration between 40 and 50 per cent $P_2O_5$ can be produced without plant modification. (5) Reactor volumes required in terms of $P_2O_5$ output are no greater than conventional dihydrate processes. (6) Only one filter is needed. This should provided four wash stages when producing a 50 per cent $P_2O_5$ acid; and (7) The evidence obtained from the pilot plant suggests that the process is less affected by impurities present in different rock sources than in the normal dihydrate process.

[*Phosphorus and Potassium*, No. 31, (1967), 27]

**Woodall-Duckham/Nordac Submerged Combustion Evaporator for Phosphoric Acid**

Wet process phosphoric acid usually produced at a concentration of 30 to 35 per cent $P_2O_5$ may be concentrated further from 54 to 74 per cent $P_2O_5$ with the help of Woodall-Duckham/Nordac submerged combustion evaporator. In cases steam at medium pressure is available from sulphur-burning sulphuric acid plants, this may be utilized economically for concentration of the phosphoric acid to 54 per cent in multi-stage evaporators. Where such steam is not available, submerged combustion plants are ideal for concentration.

For a 50-54 per cent $P_2O_5$ product, the concentrator vessel is usually square in plan view with hopper bottom. On the top, one or more burners, operating on fuel oil or natural gas, are mounted. Combustion is complete in the upper part of the burner and the gases—under pressure—bubble through the liquid. The depth of immersion of the liquid depends to some extent on the size of the burner, but is usually less than 18 in.

The concentrator vessel is operated with the contents at a constant level maintained by control on the feed rate of weak acid. Outflow of concentrated acid is continuous and the rate is normally controlled by means of a valve linked with a temperature controller activated by the boiling point of the acid, which in the case of 54 per cent acid is normally about 110°C under submerged combustion conditions.

Concentrators are normally fitted with a desludging box so that approximately once per shift any sludge settling in the concentrator may be emptied. However, in some cases this is regarded as unnecessary and the calcium sulphate formed in the concentrator may be kept in suspension by air agitation.

For superphosphoric acid there is no sludge problem and the shape of the concentrator is designed to give a liquor pool of much smaller volume.

In evaporators for 54 per cent acid, and more especially for 70-76 per cent acid, considerable care must be taken (a) to obtain a good mass efficiency, and (b) to ensure that a minimum of entrained acid is carried away up the stack into the atmosphere.

In addition to the burners, an offtake duct of wide cross-sectional area is mounted on the top of the concentrator vessel for removal of steam and combustion gases. A low offtake gas velocity permits large entrained droplets caught in a simple louvre-type entrainment separator in the top of this duct. This liquor returns to the evaporator. In the case of superphosphoric acid plants, the evaporator operates at about 350°C and the exit gases leave the liquor pool at the same temperature. Special sieve plates are therefore fitted in the offtake duct to permit heat recovery, the weak acid being fed to the top plate. The $P_2O_5$ mist, which is not separated in this manner, is recovered in a hot-recycle type wet scrubber device followed by a cyclone. The scrubber system can be operated at any convenient $P_2O_5$ strength up to about 50 per cent $P_2O_5$. The acid recovered in this way is returned either to the phosphoric acid plant or to the $P_2O_5$ concentrator feed.

In the $P_2O_5$ scrubber only small amounts of fluorine compounds are removed; the fluorine is present largely as silicon tetrafluoride ($SiF_4$) and hydrogen fluoride (HF) and it is not possible to filter these from the gas stream. However, if the gas stream is cooled considerably these combine to produce fluosilicic acid ($H_2SiF_6$), which can be removed as droplets of an aqueous solution. A high-efficiency filter incorporating a special disposable cloth has been developed for this purpose. The stream leaving the $P_2O_5$ scrubber is therefore passed through a multi-stage direct-contact

condenser system to lower the temperature to 30°C, the optimum level. The fluosilicic acid can, if desired, be neutralized with sodium carbonate to precipitate sodium fluosilicate ($Na_2SiF_6$), which is then filtered off.

As a result of this gas treatment, $P_2O_5$ losses are reduced to less than 0.5 per cent and fluorine emission from the stack is reduced to 2-10 mg/$Nm_3$ which is very low.

[*Phosphorus and Potassium*, No. 31, (1967), 29]

**Release of Nitrogen from Coal Fertilizer**

Available nitrogen in coal can only be judged by biochemical tests including the crop response. The utilization of nitrogen by plants from coal fertilizer had been rather slow but when it was mixed with another nitrogenous fertilizer as urea, the nitrogen utilization from coal fetilizer appeared to have improved considerably. Coal fertilizer applied in a mixture with urea and calcium ammonium nitrate was actually found to give better yield of potato tubers than coal fertilizer alone. Pot culture experiment on lettuce with coal, urea and mixture of two gave similar results. It has been found that the mixture of coal fertilizer and urea has given more number of leaves and more width of the leaf but the leaves produced were dwarfs. Application of the mixture has given 6.4 per cent higher yield by weight of lettuce over urea alone (where the amount of nitrogen applied was same) and 32.0 per cent higher yield over coal fertilizer alone.

During coal fertilizer field trials it was reported that the wheat and paddy plants appeared yellowish (less green) during the early period of growth but this character was unnoticeable after the plants had attained sufficient height. During pot culture studies it was recorded that the yellowing did not occur when coal fertilizer was applied 2 weeks before the sowing of seeds. Yellowing and stunted growth in corn plants were observed where exceptionally heavy dose of coal fertilizer was given. These were ascribed to a C/N imbalance or trace element/phenolic/other toxicity present in the coal fertilizer. The pH of the soil was found to be slightly lowered due to the application of coal fertilizer.

It is quite probable that certain phenols are formed due to the partial oxidation of coal during air/ammonia treatment. These phenols might have been responsible for temporary yellowing that vanished later due to its dilution and microbial oxidation with simultaneous release of nitrogen. 0.10 per cent phenols were estimated in a 1 per cent alkali extract (after boiling for one hour) of a coal fertilizer sample.

Nitrification studies with coal fertilizer have revealed that no extra amount of nitrate was released in the soil when coal fertilizer was added as such while nitrification of urea was normal. During similar preliminary studies with a mixture of coal fertilizer and urea it appeared that release of some amount of nitrate was brought about from coal fertilizer. More experiments are underway to confirm the same. The above observations give a ray of hope that if coal fertilizer is applied along with another nitrogenous chemical fertilizer, the release of nitrogen from coal material might be enhanced significantly. It may be due to the abundance of nitrogen from the soluble chemical fertilizer available to the soil microflora; a great deficiency of available carbon is likely to be created that in turn may be fulfilled by the carbon from coal material especially under the starvation conditions. Further, the release of nitrogen from coal fertilizer, being a slow process, is distributed over a longer span of time ensuring proper utilization of the far greater part of its nitrogen by the plants whereas the utilization nitrogen from ammonium sulphate etc., is only one-third to half of the soluble nitrogen, the rest of it being lost through leaching, volatilization, etc. Proper utilization of nitrogen by the plants is a very important consideration since plants can only assimilate nitrogen slowly throughout its life period. The soluble chemical fertilizers, however, provides the nitrogen in heavy concentrations all at once.

A quantitative assessment of bacterial population per g. of dry soil was carried out with soil samples collected at the end of the nitrification studies. Viable bacterial counts showed 310 million organisms in coal fertilizer treated soils as against 229 millions in urea treated and 195 millions in control samples. Though the amount of nitrate released was practically nil, the bacterial activity in coal fertilizer treated soil appeared to be high. It is quite likely that bacteria other than nitrifiers were active. They might have been phenol oxidizers or non-symbiotic nitrogen fixing bacteria like Azotobacter etc. It will be worthwhile to study what is the type of organisms whose growth is accelerated by the presence of coal fertilizer and which is that component of coal fertilizer responsible for this action. Further investigations on the above lines are in progress.

For a correct appraisal of the amount of oxygen, which is one of the parameters in determining the rank and possible utilization of any coal, estimation of nitrogen is essential. Conventional method of estimation of nitrogen by Kjeldahl method is a time consuming one. Hence, an attempt was made at CFRI[1] to evolve a quick and accurate method of estimation of nitrogen.

The underlying principle of the method is to convert the nitrogen present in coal into ammonium sulphate by interaction with either potassium persulphate, selenium powder and sulphuric acid or manganese dioxide and sulphuric acid, oxidize the ammonium salt to nitrogen with hypohalite and back titrate the excess of hypohalite iodometrically. Before titrating iodometrically, interfering actions of Mn-ions and selenium were avoided by using sodium carbonate and sulphurous acid respectively.

The results of nitrogen estimation by the Kjeldahl method and the present one were found to be comparable within limits of experimental errors.

[*FRI News*, **16** (4) (1966), 135]

**Polythene-lined Jute Bags to Store Nitro-Phosphates**

Storing of nitrophosphates poses a difficult problem because of the presence of calcium nitrate, a hygroscopic compound. Keeping the fertilizers in the air-tight containers is no doubt a reliable method but it is a costly affair and commercially not feasible. Therefore, various experiments are still carried out to find a suitable container for nitrophosphates to reduce moisture absorption and consequent losses of nitrogen.

One of such experiments carried out by Agricultural College and Research Institute, Coimbatore-3 (Madras) showed that polythene-lined jute bags are more suitable for sulphonitric nitrophosphate (12.9: 12.9). The nitrophosphate used in the trial was analysed to 7.62 per cent and 5.52 per cent for ammoniacal and nitrate nitorgen contents while its water-soluble and citrate-soluble phosphoric acids were 5.28 and 7.93 per cent respectively. This fertilizer was studied for its storage properties keeping it for seven months in ordinary jute bag, thick paper-lined jute bag, polythene-lined jute bag, polythene-bag, bottle and tin.

The chemical analysis, after experiment, showed that moisture content in ordinary

bag and thick paper-lined jute bag increased considerably than the other containers. Polythene-lined jute bags and polythene bags were found to be on par with air-tight bottle and tin container. As mechanical strength is required for storage containers, from commercial point of view polythene-lined jute bags are found more suitable for storage of sulphonitric nitrophosphate.

[*Madras Agri. J.*, **54** (11) (1967), 587]

**Technifoam Insulation for Anhydrous Amomonia Storage Tank**

Storage of anhydrous liquid ammonia in hemisphorically-roofed tank of 15,000 s.ton capacity, 64 ft. high and 120 ft. in diameter, at constant temperature of—28°F requires high degree of insulating efficiency and a search for a new insulating material. The huge tank was constructed by General American Transporation Co., for Geismar La Allied Chemical Crop. An insulating product, called as Technifoam 720 developed by Allied's Fabricated Products Division was used for this purpose.

TF 720 is a sandwitch board consisting of core of rigid urethane foam between supported aluminium foil facer sheets. In addition to insulating efficiency, it is claimed that it has a high moisture vapour resistance and being light in weight it can be applied in large sheets thereby simplifying installations. Also it can be cut easily and shaped and can even be bent to conform to round surfaces such as storage tanks, without damage to core or facer sheets.

Two layers of TF 720—each in 1½ in. thick—were applied to the tank. It is said by insulating contractor that 3 in. thickness of TF 720 provides as much insulation as 5 inches of polystyrene and 7 inches of cellular glass.

On the side walls of the tank 3 ft. by 4 ft. panels of the foam material were used. All joints were staggered. The edges of the first layer were ship-lapped and were laid up without an adhesive. They were secured with nylon strapping. The second layer was installed with all joints batted and caulked with vapour barrier sealant. This layer was secured with stainless steel bands. Following the installation of TF 720, the side walls were coated with mastic sprayed in place. A white glass-mesh membrane was then embedded in the mastic and second coat of the mastic was applied on top of the glass membrane. The roof of the tank was insulated in almost the same manner, with the difference that 2 ft. by 4 ft. Technifoam panels were used and that the first layer of insulation was secured by clips and had been previously welded to the bare roof.

Several months have elapsed since the tank insulation was completed, and during this period the required temperature of —28°F has been maintained.

[*Nitrogen*, No. 49, (1967), 38]

**Purification and Concentration of Wet Process Phosphoric Acid**

Phosphoric acid produced by wet process contains only 30-32 wt. per cent $H_3PO_4$ and many impurities, therefore it is used for fertilizers and detergents, while the thermal process phosphoric acid containing 85 wt. per cent $H_3PO_4$ and relatively free finds use as "food-grade" acid. A competent purification and concentration process for wet process phosphoric acid based on solvent extraction is announced by Toyo Soda Co. of Japan. It claims that equipment can be added at the end of the crude acid plant quite easily and either food, detergent or fertilizer grade acid can be produced according to seasonal demands.

The crude acid from the wet-process operation is first decanted and treated chemically in a pre-purification stage which removes a certain amount of the impurities present. This is followed by mixing with an aliphatic alcohol, which is the key to the process operating economically. The alcohol concentrates most of the acid into a solvent-rich extract stream. Some of the solvent dissolves in the dilute acid stream and this is recovered in the solvent recovery plant, the dilute acid returning to the fertilizer acid plant.

The acid-rich solvent is washed with water and the phosphoric acid dissolves preferentially in the water-rich phase. The organic phase is added to the alcohol recovered in the solvent-recovery plant and then recycled and used for further extractions. Following the removal of the aliphatic alcohol, the acid is free from most of the impurities originally present, but is still in a diluted state. The excess water, and also the remaining traces of the solvent, are removed by evaporation to give a relatively pure and concentrated product suitable for use in the detergent industry since it is now free of iron, aluminium, calcium, fluorine and sulphate impurities. To obtain "food-grade" acid, a further purification must be carried out to remove trace metals, contaminants and also any arsenic that may be present. This is done by passing the acid through a bed of activated carbon.

As regards economics, the additional investment for a wet-acid producer would be $ 1.1 million for "food-grade" acid and the purification cost would be about $ 17/tonne. If the last figure is added to a typical figure for the production cost of wet phosphoric acid, say $ 70-80, an overall figure of $ 87-97/tonne $P_2O_5$ is obtained. This compares favourably with the figure of $ 100-130/tonne which has been published as being the cost of producing high-grade acid in an electric furnace.

TOYO SODA PROCESS FOR PURIFICATION OF PHOSPHORIC ACID CHEMICALS, UTILITIES AND LABOUR REQUIREMENTS

| | Units/tonne $P_2O_5$ | |
|---|---|---|
| | Technical grades | Food grade |
| Chemicals | | |
| For impurity removal | * | * |
| Solvent (lb) | 6.6 | 6.6 |
| Activated Carbon | —— | 6.6-11.0 |
| **Utilities** | | |
| Steam (s. tons) | 1.5 | 2.5 |
| Electric power (kWh) | 50.0 | 110.0 |
| Process water ($m^3$) | 1.5 | 2.0 |
| Cooling water ($m^3$) | 60.0 | 100.0 |
| **Labour** | | |
| Men/shift | 1 | 3 |

*Varies with impurity content of crude acid feed.

[*Phosphorus and Potassium*, No. 30, (1967), p. 23]

**Fertilizer with 80-85 per cent Water-Soluble $P_2O_5$**

A process for the production of 80-85 per cent water soluble $P_2O_5$ and 0.66 ratio of $N/P_2O_5$ fertilizer will be very soon streamlined by Norsk Hydro. It will be manufacturing the high grade products such as 23-23-0, 17-11-15, 15-9-22, 15-9-15 and some of the products will contain the micronutrients like magnesium, sulphur and boron. The plant is based on the extensive knowledge obtained by the firm during the last thirty years and equipments for crystallization, filtration, evaporation, mixing and prilling are entirely based on their own design. The capacity of the plant is 1,500 t.p.d. (finished product) using raw

materials Kola rock (85 per cent TPL) nitric acid, ammonia, potassium chloride (60 per cent $K_2O$) or potassium sulphate. The process removes main disadvantages of the conventional Odda process i.e. low analysis of the product and small amount of $P_2O_5$ present in water soluble form. In this modified process, it is claimed that the prilling of the NP or NPK products with formulations 30-10-0, 28-14-0, 23-23-0, 20-30-0, 13-20-20, 16-16-18, 23-11-11, 15-22-22, and 13-13-26 is possible.

The process principle is more or less the same as that of Odda process. Phosphate rock and nitric acid (58-62 per cent $HNO_3$) are mixed in the acidulation vessels utilizing a small amount of excess acid to obtain optimal conditions during acidulation, crystallisation and neutralization. The acid solution is passed to a number of crystallizers where the temperature is reduced. The final temperature in the solution will determine the amount of calcium nitrate to be removed, and also the water solubility of the phosphate. The necessary minimum amount of calcium nitrate that in any case must be removed to avoid formation of insoluble tricalcium phosphate during neutralization, requires cooling to about 18°C. The corresponding water solubility is about 20-30 per cent. Cooling to about 12°C will normally give about 50 per cent water-soluble $P_2O_5$, while the temperature in Norsk Hydro's new plant will be about -5°C, giving about 80-85 per cent water solubility.

After crystallization the calcium nitrate tetrahydrate is removed on filters specially constructed to handle this material, and can thereafter be passed into the conversion plant for converting calcium nitrate to calcium carbonate and ammonium nitrate or calcium ammonium nitrate fertilizer. The calcium nitrate can alternatively be processed to prilled calcium nitrate.

The mother liquor, after filtration, is neutralized with ammonia concentrated to less than 0.6 per cent water, mixed with potassium salts and micronutrients, if required, and prilled. Hot prills leaving the bottom of the tower are cooled and coated with a suitable coating agent before the product is passed to storage.

Economics of the process will be governed by the cost of ammonia prevailing in that particular locality. Capital investment will not be more than that of sulphuric acid route, but operating cost will be significantly lower. Attractive feature will be that it avoids requirements for separate sulphuric acid and phosphoric acid facilities. The firm indicates that a turn-key plant of 600,000 t.p.a. capacity (grade 16-16-18) will cost about US $ 10 million.

The following table shows the requirement of the raw materials, utilities and by-products obtained.

NORSK HYDRO NITROPHOSPHATE NPK PROCESS-RAW MATERIALS, BY-PRODUCTS AND UTILITIES

| (tonnes/tonne product) | Grade 16-16-18 | Grade 23-11-11 |
|---|---|---|
| Raw Materials | | |
| Kola rock (85% TPL) | 0.42 | 0.28 |
| Nitric acid (100%) | 0.69 | 0.45 |
| Ammonia (100%) | 0.23 | 0.15 |
| Potash (60% $K_2O$) | 0.30 | 0.18 |
| Carbon dioxide | 0.15 | 0.10 |
| Coating agent | 0.0015 | 0.0015 |
| *By-products* | | |
| Ammonium nitrate (100%) | 0.49 | none |
| Calcium carbonate (100%) | 0.33 | 0.22 |
| *Utilities* | | |
| (all grades, approx. per tonne product) | | |
| Steam | 0.9 tonnes | |
| Cooling water | 13.0 tonnes | |
| Power | 65.0 kWh | |
| Instrument air | 6 $m^3$ or 200 $ft^3$ | |
| Scrubbing water | 10.0 tonnes | |

[*Phosphorus and Potassium*, No. 30, (1967), 22]

**Ammonia Synthesis Catalysts**

The method of manufacture, its composition and the conditions of using have a definite influence on the activity and life of the ammonia synthesis catalyst. The prolonging of its useful activity is now becoming important. Though it would be more economical with regard to the yield to work with a pressure range of 300 atm and with an ammonia content of 6 per cent within the feed gas under operating temperatures above 550°C, a greater concentration of ammonia is deliberately avoided in order to maintain the initial activity of the catalyst as long as possible. Also, the removal of impurities in the synthesis gas feed has to be taken into consideration. Besides, methanization i.e. coversion of oxygen compounds to methane and water has assumed importance; the water formed in this process is removed from the synthesis gas.

Most ammonia synthesis catalysts contain as main promoters, $Al_2O_3$ and $K_2O$, other promoters being MgO and $SiO_2$; besides these, there are the metal oxides LiO, $Na_2O$, $Cs_2O$, BeO, MgO CaO, SrO, Bao, $B_2O_3$, $La_2O_3$, $ThO_2$, $ZrO_2$ CeO, $TiO_2$, etc. These oxides increase stability at high temperature and resistance to poisoning. The types more resistant to temperature and poisoning contain upto 3 per cent CaO and MgO. More recently, $SiO_2$ (upto 1 per cent) has found wider use. Thus, a Bulgarian catalyst (designated K-31) contains $Al_2O_3$ (3.9), $K_2O$(1.8), CaO (2.3), Mgo (0.4) and $SiO_2$ (1 per cent). Since modern ammonia synthesis units are designed to keep the converter temperature below 500°C and to prevent the CO content of the feed gas exceeding 5 ppm, catalysts having high CaO and MgO are not useful, since with highly promoted catalysts the achievement of resistance to poisons and elevated working temperatures is brought dearly by a reduced activity. In addition to the concentration of promoters, the proportion of bi-/to trivalent iron has also an important bearing on catalyst activity.

Apart from melting the different raw materials, the more recent method of making the catalyst is of sintering the well premixed components. In carrying out the melting process, care must be taken to ensure that the admixed promoters and magnetite form a homogeneous melt. The time taken by the melt to cool has a definite influence on the catalyst's property. The type of crushing appliance is of considerable importance to the grain structure; it is possible to treat the surface of the screened grain to increase the catalyst activity by at least 5 per cent.

The oxidic ammonia synthesis catalyst is not yet ready for production and therefore must be first converted into its active form by reduction. Some manufactures offer fore-reduced catalysts viz. those already converted to the active form. The commonest way of deactivating the catalyst is by treating with nitrogen to which an increasing amount of oxygen is added after the converter cools down.

The commonest poisons decreasing (temporarily or permanently) the catalyst activity are mainly oxygen and sulphur compounds, phosphorus, arsenic, unsaturated hydrocarbons, etc.

[*Brit. Chem. Engng*, **12** (11) (1967), 1745]

**Talcher Integrated Complex**

This complex, planned by the Industrial Development Corporation. of Orissa Ltd., is a project based on the utilization of the non-caking coals of Talcher (Orissa), the total reserve of which is estimated at 153.8 m. tonnes. Other raw materials like iron ore, limestone and manganese and utilities, like water and power, are also available nearby. Of the 3 coal seams at Talcher, the lower one is most important, being superior, and therefore it is proposed to be utilized. The upper seam is high ash and therefore will be utilized for power generation.

During the Fourth Plan about 1,000,000 tonnes of Talcher coal will be raised annually by the NCDC, based on which it has been worked out that only 5,30,000 t/a of sized coal (-100+30 mm) will either be washed or directly taken (if ash is less than 14 per cent) to the coke ovens. 1600 tonnes/day will be carbonized to produce about 960 tonnes coke. Coke (+20 mm.) amounting to 2,58,000 (dry) t/a will be taken to four low-shaft furnaces to produce 1,68,300 t/a of pig iron. While the slag can be profitably utilized for slag cement manufacture in the near future, the gas from the low shaft furnaces will be utilized to heat the stoves of the furnaces and the balance will serve as fuel gas for heating the coke ovens and boilers. The entire coke oven gas can be converted into synthesis gas after reforming its methane content for finally making urea. The annual production of saleable items based on a 420 t/day urea plant is as follows (tonnes): pig iron 1,68,300; urea 1,38,600; ammonium sulphate 11,000; road-tar 16,000; fuel oil 10,900; pure benzol 3,500; toluol 800 and solvent naphtha 700. Based on the above amount of urea production, the total capital is estimated at Rs. 350 million (pre-devaluation rate) and the foreign exchange component would be about Rs. 100 million.

[*J. Mines, Metals and Fuels*, **15** (12) (1967), 359]

**Fertilizer Industry Round Table* 1966**

The sixteenth annual round table meeting held in five sessions during Nov. 2-4, 1966 discussed most of the aspects of the fertilizer industry. Right from the population explosion which will demand more fertilizer to feed the increased mouths up to the distribution pattern of fertilizer was debated in a very lucid manner. The meeting dealt in detail with supply of raw materials, various economic factors relating to the production, development of some new products and processes, latest addition of new equipments, etc.

*Demand and Supply of Fertilizers*: The discussion started from problems of demand and supply of fertilizers and changing agribusiness where W.B. Copeland struck a note of optimism. He pointed out that to meet the increasing demand of food the two ways are left, i.e. expanding the area under cultivation which has got its obvious limitations and second, raising the yield/acre. As regards the problems of future supply, he was confident that except availability of sulphur for phosphatic fertilizers, remaining plant nutrients can easily be available.

Neal G. Schenet added to the above discussion by giving an illuminating analysis of the fertilizer explosion with a marketing angle. A phenomenal increase in the world fertilizer consumption began in 1963 with an increase by 10 per cent—and in the following years 10, 20 and 9 per cent (estimated) respectively. The reasons for this are: increasing population and demand for higher standard of living, better farmer education, higher governmental priorities being given to fertilizers, incentive factors like profitability, increase of fertilizer consumption per acre in advanced countries (e.g. Japan 270 lbs, Netherlands 410), shortage of arable land, etc. This explosion of fertilizer demand will have to be met, and by 1980 it will be around 113 million tons. Taking 30 million tons consumption in 1962 for increase of 83 million tons, Schenet gave the following breakdown: 20 m. tons to feed growing population; 13 m. the increasing standards of living, manifesting themselves in terms of more consumption; 15 m. to replace the nutrients that are removed from the soil; 20 m. to meet the more demand created by farm capitalization; 15 m. Government action, expanding technology, etc.

THE PRESENT PLANNED AND REQUIRED CAPACITIES (M. TONS/YR) ARE AS FOLLOWS:

| Present Capacity | | After Planned Construction | Requirement by 1980 |
|---|---|---|---|
| Nitrogen | 20 | 32 | 51 |
| Phosphorus | 14 | 23 | 33 |
| Potassium | 13 | 21 | 29 |
| Total | 47 | 76 | 113 |

While emphasizing the need of the aglime industry, Robert M. Koch, pointed out that the lack of agricultural limestone is a limiting factor especially in humid area. He felt that the enormous growth of fertilizers during recent years retains the requirement of aglime because most of the authorities agree that 300 lbs/yr of N for 5 years require an application of 3.5 tons of aglime to compensate for the developing acidity. By 1970 world use of N is estimated at 29.5 million metric tonnes and just to maintain the *status quo* of the use of the same, the aglime required will be 39.395 million metric tonnes.

In comparing the *relative cost of granulating and blending* in manufacturing ammoniacal fertilizers, according to Grant C. Marburger, two points are important, viz. use of basic material and integrated plant material cost (Table).

TABLE—COST OF GRANULATED 15-15-15 AS COMPARED WITH 15-15-15-BULK BLEND

| | Granular | Bulk Blend |
|---|---|---|
| Materials | $ 33.57 | $34.57 |
| Plant Operating Costs+ | 6.00 | 6.00 |
| Operation of Distribution Station* | 2.00 | |
| Freight to Distribution Plant | 4.00 | |
| Sales Cost | 00.00 | 00.00 |
| TOTAL | $ 45.57 | $ 40.57 |
| COST DIFFERENCE | | $ 5.00 |

[*Includes depreciation but not interest.]

This discussion makes an end of the first session.

*Proceedings of the 16th Annual Meeting, Fertilizer Industry Round Table held at Washington (USA), Nov. 2-4, 1966 pp. 120, $ 6.00

*Ammonia—Safety and Storage:* Since the use and production capacity of ammonia is increasing, it is necessary to know its effect on the skin and safety measures to be taken. Transferring of liquid ammonia in plant and its storage are also equally important. These points were briefly dealt with by B. F. Day, in the second session. Exposure to atmospheric concentrations of ammonia above 5,000 ppm, or 1/2 of 1 per cent by volume, can produce death by suffocation within minutes, or 2/10 of 1 per cent can burn and blister the skin after a few seconds' exposure. Liquid ammonia in contact with the skin can produce severe burns, because of its strong corrosive action and the freezing effect produced by its rapid evaporation. Concentrations above 700 ppm., not treated immediately, may lead to partial or total loss of sight. Prolonged exposure to atmospheric ammonia above this concentration may produce severe scarring of the exposed eye tissue, especially the cornea.

There are two general classifications of ammonia storage tanks: (1) high pressure and (2) refrigerated tanks; the former ranging in size from 6,000 to 30,000 gallons. The more common sizes range from 6,000 to 30,000 gallons. The medium pressure tanks, usually special and covered with 4-6 inches insulation, fall under refrigerated tanks; they are supported on steel legs and range in size from 500 to 3,000 tons capacity. A complete refrigeration unit is connected to the tank, and ammonia is used as its own refrigerant.

Atmospheric storage, a relative newcomer to the ammonia industry, is merely the refrigeration of ammonia to or below its boiling point (-28°F). Tanks of this design range from 10,000 to 30,000 tons and are usually of a double tank design—one within the other and the space in between being fully insulated.

The transferring of liquid ammonia can be divided into three general classifications by (1) using vapour compressors to produce a pressure differential between vessels; (2) positive displacement pumps, and (3) producing a pressure differential by bleeding-off vapour from the container being filled. For transferring ammonia from storage into ammoniator granulator, the rotary, positive displacement pump is used.

An important survey was conducted by the TVA to determine the changes that have occurred in *ammoniator-granulator* practices in the past five years, the findings of which were presented.

*Fluid Fertilizers and Ammonium Polyphosphate:* The recent trend towards fluid fertilizers indicates its some advantages—mainly the ease of application—over the solid fertilizers. As regards cost it is more or less equal to solid fertilizers. The average cost of storage for large tonnages of liquid fertilizer is about $ 6-7/ton of material as compared with $10-12/ton for solid fertilizer. Since the average plant nutrient content of a clear liquid fertilizer is about one-half that of solid fertilizers, the cost of storing plant nutrients as clear liquids or solids is about the same.

A. V. Slack gave a brief account of TVA's recently started experimental production of solid ammonium polyphosphate (15-16-10), by ammoniating furnace superphosphoric acid and granulating the resulting anhydrous melt in a pug mill. The product is useful both as a solid fertilizer and a base material for liquid fertilizer. For liquid fertilizer, it has the advantages of lower shipping cost as compared with 11-37-0 and of stability against hydrolysis during storage. Use in either cold/or hot-mix plants would be feasible but the latter is preferable because some ammonia must be added to get the best N: $P_2O_5$ ratio for solubility. The material can be used in cold-mix plants, even though such plants do not have ammonia spargers is the mix tanks. It will take a considerable testing period on solid ammonium polyphosphate to determine its ultimate status in the liquid mixed fertilizer industry. Perhaps one good use will be as a reserve of phosphate to serve as insurance against unavailability of phosphoric acid during the busy production season. Carbon steel is mainly used as the material of construction, but a fair amount of stainless steel is also used particularly in applicators. Plastic tanks or glass-fiber reinforced plastic seem to be growing more popular.

*Materials handling:* Bag filling equipments, conveying, stacking and loading methods require careful attention to increase the efficiency of the operation. D. O. Myers and Stewart found that material handling efficiency levels in a large percentage of plants vary from 40 to 60 per cent, and the cost of this low efficiency increases every year. The efficiency can be increased by (1) keeping the packing machines running as continuously as possible and (2) selecting bagging equipment providing a production rate to commensurate not only with total daily production needs, but customer service requirements also. The first is losses due to product analysis changes, and the second is time lost in changing from loading one carrier to another. The speakers made suggestions for improving packaging, storing and loading for maximum savings.

The Force Flow utilizes a completely new concept in fertilizer packaging. Its design originally developed in 1959 for fertilizers is based on simple pneumatics using high pressure air for its controls and low pressure air for the actual packing operation. It has no high speed roating or reciprocating parts. According to John H. Dively it satisfied the basic requirements of the industry like (1) handling wide range of packing rates (2) *pact* full range of the basic types of fertilizers, analyses, and materials (3) bags that provided adequate product protection (4) minimum labour.

*Compound Fertilizer Process*: A wide range of combinations of plant foods can be obtained by mixing together the separate components in powder form, but dry mixes of fertilizers do not spread on the land easily or uniformly and are liable to segregate in storage, during transport and compact into solid masses when stored.

To overcome these difficulties, ICI developed the production of plant foods in the form of freeflowing, uniform, non-caking granules. The pH of the fertilizer is 5.5-6; and for conditioning, less than half of 1 per cent oil is used.

Nitric acid (preferably at least 55 per cent $HNO_3$) is neutralized at atmospheric pressure with gaseous ammonia and then concentrated in special low hold-up evaporators to give 95 per cent ammonium nitrate liquor. Wet process phosphoric acid (35-45 per cent) is neutralized to the required mixture of mono- and di-ammonium phosphates in the saturators. Concentrated ammonium nitrate liquor, ammonium phosphate slurry, potash and recycled fertilizer product of controlled size grading enter the paddle mixer or lunger at controlled rates and are granulated together. The correct design of equipment to handle the rather sticky mixtures met with nitrates or urea-based compounds is very important for the successful operation of the process. The moist granules from the mixture are dried to the requisite low moisture contents necessary to give the products excellent handling properties. The dried granules are screened and the oversize component is crushed with a swing hammer type of mill. The product-stream is cooled and then coated, in accordance

with the methods designed by ICI, to give a free-flowing product.

*Conditioners*: In case of medium to high-analysis fertilizers conditioning is accomplished by controlling temperature, moisture and particle size, but industry wants storage of highly water-soluble fertilizers in bulk and also in bag in hot and humid climates, for long periods.

The critical relative humidity (CRH) plays an important role in storage. The fact that combining salts usually result in a lower CRH than that of the components is a big factor in the caking of mixtures of materials that, by themselves, store satisfactorily. The laboratory study of the moisture absorption and penetration has revealed that in cases of ammonium nitrate (CRH 59) and urea (CRH 75) moisture penetration was maximum. While urea-ammonium phosphate (CRH 60) and nitric phosphate (CRH 63) showed very little penetration the top layer was sticky. There was little penetration in the case of di-ammonium phosphate (CRH 75).

In bag-storage tests, conditioners like kaolin clay, diatomaceous earth and calcined fullers-earth have been studied. The following are some of the methods to prevent absorption of moisture in bulk storage: dehumidifying the air, to cover fertilizers either with plastic sheets, finely ground phosphate rock or limestone.

Processing and handling pose a problem, and to avoid this additives are used which act as an anti-caking and conditioning agent or penetrant, and serve to improve the product performance for the ultimate consumer. The use of liquid conditioner, PETRO Ag Special, to alter the freezing points of nitrogen solutions i.e. urea/water solution was found best. Another application of the same conditioner in 50 per cent aqueous solution, in conditioning of granulated fertilizer product of grades 5-20-20, 6-24-24 and 12-12-12-, was found satisfactory. One more application where the above liquid conditioner (0.03 per cent) has shown promise is in the treatment of run-of-pile and granulated triple superphosphate. In the production of diammonium phosphate where caking and handling problems were causing delays in shipments as well as added labour costs, this procedure showed remarkable results. The use of PETRO S, another conditioner which is completely water-soluble, in the granulation of superphosphate (less than 22 per cent $P_2O_5$) has also been studied on a laboratory scale.

*Performance of Organo-Clay Coating Agents*: The trend to high analysis fertilizers has served to intensify caking problems, despite significant advances in granulation, drying, packaging and storage. As a result, a small group of high performance inorganic agents has displaced most of the marginal mineral fillers in coating outlets. More recently, a new class of coating agents has emerged in which anti-caking performance of inorganic fillers has been significantly enhanced by surface modification with functional organic chemicals. Joseph Iannicelli has dealt briefly with organo-clays whose main advantages are low cost in certain areas, ease of handling and reduced dusting. Caking inhibition by surfactant modified fillers, like organo-sulphonates, has also been studied.

R. J. Harvey has evaluated six different classes of conditioners by four tests, viz. bulk tensile strength; powder shear strength; compressive strength; small bag storage, on potassium nitrate to establish what class and level of conditioning was statisfactory.

*Apparatus to Detect Air Contaminants:* A brief description of some of the portable instruments for measuring atmospheric contaminants was given by J. E. Zatek. An Universal Tester, developed by M/s The Mines Safety Co. Pittsburg, along with its appropriate accessories can identify some 118 different toxic materials.

*Melt Process For Granular Fertilizers:* The concentrated fertilizers are in great demand, and have undergone two major trends in recent years, one towards high concentration based on ammonium nitrate, ammonium phosphate and potassium chloride, the other of high nitrogen ratios e.g. 2:1:1 and even 2.1/2:1:1. The Levington Research Station of Fisons Fertilizers Ltd. have carried out a comprehensive study of the basic physical and chemical properties of ammonium phosphate and ammonium nitrate mixtures. They found that it is possible to produce anhydrous molten mixtures of ammonium nitrate and ammonium phosphate at temperatures below the melting points of their component salts, and that the molten N-P mixtures can be solidified in a controlled manner in any one of the conventional methods, such as rotary drum granulation, flaking or prilling to produce a product of excellent physical form, which require no further drying. Potassium chloride can also be added during the solidification stage.

A plant to produce about 200,000 tons/year of NPK or 150,000 tons/year of NP compounds would require the following utilities.

| Utility | Consumption per ton of finished fertilizers | | |
|---|---|---|---|
| | 24-24-0 | 17-17-17 | 25-10-10 |
| Electric Power kWh | 30 | 28 | 28 |
| LPsteam (15 psig). lbs | 85 | 60 | 35 |
| HP steam (250 psig). lbs. | 175 | 120 | 180 |
| Dock water (Imperial gallons) | 570 | 410 | 480 |

*Mono-Ammonium Phosphate:* The pilot results have established the promising nature of a novel, cheap and efficient process for the manufacture of a powder mono-ammonium phosphate. J.D.C. Hemsley (Fison's Ltd.) said that this process has a special attraction in that phosphate acid can be readily converted to a solid form, transported, stockpiled and used more cheaply than the acid itself, particularly when long distances are involved, Additionally, the capital investment and operating costs for such a plant would be very much less than for a plant producing granular ammonium phosphate of equivalent capacity. This process, therefore, would be particularly suitable for use by phosphate rock producers, as it represents a very cheap method of upgrading $P_2O_5$ prior to transport. The product appears to have very good properties compared with similar powder intermediates in terms of storage and handling. This process also has a useful advantage over other comparable processes for the manufacture of powder ammonium phosphate, in that no sulphuric acid diluent is required to augment the phosphoric acid-ammonia heat of reaction, and the $P_2O_5$ analysis is comparatively higher. Its bulk density is 55 lbs/cubic foot, and only slightly less than that of the granular material.

# *News in Brief*

**Fertilizer Handling in U.K.**

In order to increase the efficiency of the farming, handling and operations system of fertilizers should be efficient. Fisons Fertilizers Ltd. of U.K. investigated different handling systems involving farm haulage and spreading cycles which include loading, travelling and unloading and it is in terms of these the efficiency of farming has been analysed and assessed. The sack-handling systems used small distributors which were filled comparatively slowly from trailers or heaps in fields with bulk granular fertilizer, loading was quicker, spreader-hoppers were larger, but journeys were also larger. The farm haulage cycle was largely eliminated as a separate process by this method. Liquid systems were similar to bulk solid systems with regard to load size, loading rate and travelling distance, but lower fertilizer concentration reduced the effective size of each load by 20 per cent. The bulk granular systems provide best performance from the point of standard measure of plant food per acre and the liquid systems the least. The operating costs between sack bulk and liquid handling systems do not vary greatly, much more important, however, are the overhead costs. If large spreaders are used for small tonnages, overhead costs per ton are particularly high.

[*The World of N.P.K.S.* No. 12, June (1967), 15]

**Role of Humic Acid on the Fixation of Soluble Phosphates in the Soil**

The effect of humic acid from farmyard manure and peat on P fixation in the soil was investigated in the laboratory. Humic acid decreased the absorption of $PO_4$ ions in the soil of a dilute phosphate solution. It also decreased P fixation of granular superphosphate which was in contact with the soil for four months.

Mineral P and isotopically exchangeable P were higher in the presence of humic acid. The neutral calcium humate did not show any resolving power towards calcium phosphate.

[*The World of NPKS*, No. 14, (1967) 25]

**"Pop-up" Fertilizers are Sweeping the Corn Belt**

As growers require higher yields, more than 500,000 acres in the U.S.. Midwest corn belt were treated with "starter" fertilizers in 1966.

A so-called "pop-up" fertilizer is liquid 6-24-6 consisting of ammonium and potassium phosphates. The fertilizers should contain all the primary nutrients (N, $P_2O_5$ & $K_2O$), have a high concentration of primary nutrients—all nutrients be readily soluble in water—have a low salt index, have a high proportion of the nitrogen in the nitrate form, containing little or no urea, diammonium phosphate or other compounds that liberate ammonia in the soil and be low in chlorine, sodium and other non-essential elements.

These types of fertilizer have increased the corn yield (2-10 bushels/acre) and for all trials the average yield was increased from 90 to 96 bushels per acre.

[*The World of NPKS*, No. 12 (1967), 23]

**Slow Release Fertilizer Urea-Formaldehyde**

Most nitrogenous fertilizers because of high solubility promote early season growth for plants. Soils often become short of nitrogen late in the season, especially if heavy rains leach the nitrogen from the root zone of plants. Shallow-rooted grasses are very vulnerable to such shortage. It has been found that urea-formaldehyde, a nitrogen carrier, can help to solve this problem because it releases its nitrogen more slowly than others. By top-dressing grass with 14-3-6 (14-7-7 oxide form) fertilizer containing varying proportions of urea-formaldehyde and ammonium nitrate and by cutting grasses at different intervals, it was found that with the increased percentage of uea-formaldehyde nitrogen in the fertilizer the growth rate during the season was more uniform and the carry-over nitrogen into the following year was greater. The findings of other experiment also suggest that as much as half of the nitrogen in fertilizer mixtures can be in the form of urea-formaldehyde without causing a reduction in grass yields. But because of the high cost of urea-formaldehyde which is three times more than ordinary nitrogen fertilizers its use in likely to be limited mostly to lawns and other turf, potted plants on special suitations where cost is not a major factor.

[*Crops and Soil Magazine*, Nov. (1967), 22]

**Granular Basic Slag By CNRM Process**

Centre National de Recherches Metallurgiques, of Liege, Belgium, has developed a process for the granulation of basic slag which yields a product suitable for use as a fertilizer. In this process a mixture of slag and potassium chloride is deposited on a conveyor belt by an oscillating device. Spraying equipment above the belt moistens the slag with a solution of calcium chloride which gives the desired hardness to the granules. The basic slag is then mixed with water and a binding agent to a smooth paste while still on the conveyor belt. The product thus obtained already begins to form into granules before entry into the granulating drum. Inside the rotating drum is a scraper consisting of a seamless tube to which individual cutting arms are attached. The product granules which are still wet then led to a drying drum; the dried granules are finally screened to separate oversize and dust for recycling. A production rate of 5-52 t.p.h. finished product has so far been achieved. An average of 75 per cent of the granules are available for bagging and distribution.

[*Phosphorus and Potassium*, No.27 (1967), 20]

**Efficiency of Fertilizer Urea as Affected by Method of Application, Soil Moisture and Lime**

Over 80 per cent of prilled urea applied to a field soil with air-dry surface did not hydrolyse within 14 days. The extent of hydrolysis increased with moisture content. On soil with a surface continuously moist from a high water table hydrolysis was complete within seven days, but 65 per cent

of the applied N was not accounted for as $NH^+_4$ and assumed largely lost as gas. Urea was a less effective source of N for pasture grasses than were $NH^+_4$ salts or $Ca(NO_3)_2$. The efficiency of urea was increased by rain immediately following application. Liming depressed responses to urea. Covering urea after its application or applying it to a temporarily moist soil did not increase its efficiency compared with applying it to dry soil.

**Distribution of Phosphorus in Soils After Fertilization with Superphosphate or Basic Slag**

The transformation of fertilizer phosphorus was investigated in long-term field trials on soils which has received increasing applications of basic slag or superphosphate. Phosphorus accumulation was restricted to the plough layer. 20-50 per cent of this total phosphorus was organically bound, the amount being independent of fertilizer application. Of the inorganic P fractions only P(Al), P(Fe) and P(Ca) contents were influenced by fertilization. The accumulation of P(A1) and P(Fe) was most important in all plots. With basic slag fertilization there was a tendency to accumulate less P(A1) and P(Fe) than with superphosphate. The effect on pH resulted in smaller P(A1)+P(Fe)/P(Ca) quotients after basic slag application than after superphosphate application. In all trials type and amount of P fertilizer did not result in significant differences between types and quantity of newly formed P compounds. There is only a tendency for different distribution of the P fractions to occur.

**Israeli Mining Industries Designs Liquid Mixre-Settler**

A two-tank system has been designed by Israeli Mining Industries for the manufacture of wet-process phosphoric acid. Incoming liquids are mixed in one tank and then conveyed to an upper chamber by a turbine-type pump inside a centrally located draught tube. The mixed liquids flow down to the second tank, where they settle out into light and heavy phases, the light phase being collected by overflow while the heavy phase is removed from a bottom-fed barometric "leg".

This design may also be utilized for any liquid-liquid extraction process whose final products can be separated by gravity. The floor area required for a typical separation is 8,000 ft², of which the settler tank accounts for 1,900 ft². Capacity is determined by the feedstock used and flow can vary from 55 to 1,100 gal/min. Mixing-settling rates of 8.5 gal/ft²/min may be obtained in certain cases. A wide range of metals, plastics and linings may be used in the construction of the system owing to its simple design.

Israeli Mining Industries has already granted licences to two Israeli manufacturers and is reported to be considering potential licensees abroad.

[*Phosphorus and Potassium*, No. 31, (1967), p. 45]

**High Winter Rainfall Increases N Need of Potatoes**

It has been found by Levington Research Station from experiments conducted in various parts of Great Britain that winter rainfall is a factor determining the nitrogen requirement of potatoes.

Eath experiment tested four rates of each nutrient in all combinations and both total and riddled yields and quality data were obtained. The principal conclusion drawn from the experiments was that the nitrogen requirement of potatoes was influenced by previous cropping and the amount of rainfall during the preceding winter. Although there were smaller yield increases following an application of phosphate to soils with a high phosphate status, the optimum rates for phosphate application were found to be at least 120 lb per acre of $P_2O_5$. The optimum rate of application of potash was found to be related to the amount of citric-soluble potash present in the soil.

The yield of large tubers was increased by both nitrogen and potash, while phosphate increased the yield of medium tubers more than large ones. Some small nutrient effects on tuber quality were found. Potash often depressed the dry-matter content, while nitrogen sometimes affected texture and flavour, but these effects were small in relation to those of climate, season and soil.

[Birch, Devine, Holmes and Whitear, *J. Agr. Sci.*, 1967, 69; *NPKS Abstracts*, 15, (1967), 24]

**Fertilizer Production Using Atomic Energy**

The Chairman of the Atomic energy Commission, Dr. Vikram Sarabhai, has proposed large-scale manufacture of fertilizers using atomic energy, which will increase food production by 5-7 million tons. The hydrogen can be obtained by the electrolysis of water, using atomic energy. In the case of phosphatic fertilizers, the need to import sulphur can be eliminated by producing phosphorus by the electro-thermal process. The very low cost of atomic power can be used to radically change the present power pattern. If large agro-industrial complexes are set up around massive atomic power establishments then the bulk of the power will be used by agro-industrial complexes and only the surplus will be fed to the grid. The Atomic Energy Commission has set up a working group to examine the possibility of setting up such atomic energy-cum-agro industrial complexes in the country.

[*Oil Commentary*, **5** (7) (1967), 7]

**Manufacture of Fertilizers**

Indigenous manufacture of fertilizers is lagging behind the target. The requirements of nitrogenous fertilizers during 1968-69 are estimated to be 1.7 million tonnes, while the indigenous production is expected to be 650,000 tonnes of nitrogen. The gap is proposed to be met as far as possible by imports.

(SOURCE: Rajya Sabha, 20.12.67)

[*Oil Commentary*, **5** (9) (1968), 10]

**Assam Coal for Fertilizer Industry**

The Regional Research Laboratory, Jorhat, undertook extensive research to find alternative avenues for the utilization of sulphur-rich Assam coals. In a report entitled "An Outline of a Proposal for Setting up an Integrated Coal Fertilizer Complex in Assam Valley", submitted to the Coal Board, the RRL has given the technical festibility and the cost economics of a process, based on Assam coal and capable of producing 44,700 tonnes of ammonia, 43,800 tonnes of ammonium sulphate and 6,83,100 tonnes of urea.

The process essentially consists of depelletisation of 2000 tonnes of Assam coal per day in a fluidized bed and processing of by-products to middle distillates. The fluidized char is subsequently gasified for ammonia synthesis and for the production of ammonia, ammonium sulphate and urea. The capital cost involved has been preliminarily assessed at Rs. 67 crores, while the annual recurring expenditure has been placed around Rs. 18 crores.

[*Oil Commentary*, **5** (8) 1967), 4]

**Production Cost of Fertilizers**

The cost of production varies with the type of fertilizers manufactured, the product mix, the size of the plant, its location, cost of materials and utilities. Several assumptions that would rarely be applicable in practice have to be made in arriving at

comparable cost figures for the three types of plants viz. coal, naphtha- and ammonia-based. As a generalization, it can, however, be stated that coal-based fertilizers would cost slightly more to produce than in the other two cases. The foreign exchange component of the capital cost of napptha-based plants at Durgapur and Cochin of 1000 tonnes/day of urea is Rs. 16.4 and Rs. 17.2 crores respectively.

(Source: Lok Sabha, Dec. 7, 1967)

[*Oil Commentary*, **5**(8) (1967), 22]

**Price of Natural Gas in Assam and Gujarat**

Natural gas is being produced in Assam by Oil India Ltd., and in Gujarat by the Oil & Natural Gas Commission, and the production costs vary from place to place depending on the geological formation of the structure, the nature of the gas, the quantity of gas produced and the period of depreciation and amortisation. As these factors are not identical or comparable in the two cases, it is not possible to give comparative figures of the production costs.

The price of natural gas sold by Oil India Ltd. in Assam varies from Rs. 8.77/1000 cu m. ex-field to Rs. 52.66. The price of gas produced in Gujarat has been fixed by the arbitrator at Rs. 56.00/1000 cu. m. ex-field.

The areas in which natural gas can be economically transported and distributed depend upon the quantity produced, the nature and extent of the demand and the availability of alternative fuels or feedstocks. The effect of these factors is to limit the utilization to area of economic supply. In the case of crude oil, however, the location of the refineries is the factor that determines its distribution and the diverse means of transportation available give greater flexibility to areas of utilization.

(Source: Lok Sabha, Dec. 7, 1967)

[*Oil Commentary*, **5** (8) (1967), 20]

**Ammonia Plant Emphasizing Heat Recovery**

The world's largest ammonia plant, 1500 tons/day single-train, at the Standard Oil Co. Pascagoula Miss. (USA) is designed to maximize heat recovery. Natural gas received from an off-shore field via an 80-mile pipeline is steam-reformed at 500 psi. The efficiency of the compressor that boosts the synthesis gas to 3,200 psi is increased by first passing the lower pressure inlet gas through a secondary reformer, shift converter, Cata Carb carbon dioxide removal system, methanator, and intermediate steam generators. The gas reaches the suction of the synthesis gas compressor at about 400 psi. Low poerating cost gas and steam turbines drive the centrifugal-air and synthesis gas compressors. The radial-flow reactor provides a further saving in compression power. Pressure drop in the synthesis gas converter is only about half, and heat is saved by drying the synthesis gas as it enters the ammonia converter.

*Chem. Engng*, **74** (25) (1967), 94

**Ammonia Pipeline**

The E. German pipeline of 50 km total length for liquid ammonia, now under construction, is expected to be complete very soon. It will run from Leuna to Bitterfeld with intermediary outlets. It is expected that 200,000 tonnes of ammonia will be pumped annually in this pipeline.

[*Nitrogen*, No. 49, Sept/Oct. 1967, 40]

**FCI's Agreement with Bulgaria**

An agreement has been signed on March 30 between FCI Ltd. and Techno-Export of Bulgaria for the installation of an 880 tons/day sulphuric acid plant at Sindri. This plant by using by-product gypsum from a phosphoric acid plant—to be installed under the Sindri Rationalization Scheme—will obviate the necessity of using gypsum as a raw manufacture of ammonium sulphate. Of the total cost of Rs. 6.33 crores for erecting the sulphuric acid plant, Rs. 2 crores, in the form of equipment and technical assistance, will be provided by Techno-Export. Payment will be made in rupees on a deferred basis at an interest rate of 2.5 per cent annually, under Indo-Bulgarian Credit Agreement. The plant, which will be the first of its kind and size installed so far in India, is expected to be erected within 30 months from the effective date of contract.

[*FCI News*, **6** (4) (1968), 3]

**Nangal Unit Sets Production Record**

The Nangal Unit of FCI Ltd. has set up an all-time record for producing calcium ammonium nitrate (3,10,656 tonnes) of 25 per cent nitrogen concentration. It also produced 10,326 kg. of heavy water.

This unit has also been awarded for the second year in succession a certificate of honour by the National Safety Council of U.S.A. for outstanding safety record in fertilizer industries in the world. The Govt. of India have also awarded a silver cup along with a cash award of Rs. 2,500 for the biggest reduction in the frequency of accidents in 1967-68.

[*ibid*, 2]

**Sindri Rationalization Scheme**

A Rs. 23 crores rationalization scheme for the Sindri Unit of FCI Ltd. has been drawn in order to release dependence of production at Sindri from Rajasthan gypsum, which is of a poor quality. Under this scheme, rock phosphate and pyrites will be used, instead of gypsum, as raw materials. Three additional plants, viz. Sulphuric acid, phosphoric acid and granulated triple superphosphate plants, will have to be installed at Sindri. As a result, 1,56,450 tonnes of $P_2O_5$ will be available additionally, while nitrogen capacity will be stabilized at 1,17,000 tonnes.

[*ibid*, 4]

**Town Gas from Naphtha**

The successful operation of a new process for converting naphtha to 550-Btu town gas has been proved in a full-scale commercial unit at Panama. With minor changes the unit may be operated to produce 1000-Btu gas for base load operation or peaking natural gas. The process is a continuous thermal cracking technique without refractory brick or catalyst. It can use LPG, gasoline or heavy naphtha fuels.

[*Oil Commentary*, **5** (10) (1968), 23]

**Catalysts for Fertilizer Industry**

The following leaflets have been issued on some of the catalysts developed in this Division of the FCI Ltd: (1) Low Temperature Conversion Catalyst for the Production of Hydrogen & Synthesis Gas CD-LT-21; (2) CO-Conversion Catalyst for the Production of Hydrogen and Synthesis Gases CDC-63; (3) Steam Methane Reformation Catalyst for the Production of Hydrogen & Synthesis Gas CDR-66 A; (4) Steam Naphtha Reformation Catalyst for the Production of Hydrogen and Synthesis Gases CD-RN-33; (5) Steam Oxygen Methane Reformation Catalyst for the Production of Hydrogen & Synthesis Gas CDR-66 B; (6) Methanation Catalyst for Trace Removal of CO & $CO_2$ by Hydrogenation CDM-15; (7) Zinc Oxide Catalyst for Desulphurization of Feed Stock CDZ-6.

# STATISTICS

TABLE 1—Fixed Capital Cost Estimate for Complex Fertilizer Factory—India and U.S.A.

| Item | Rs. per annual tonne of Plant Food (N+P) | | |
|---|---|---|---|
| | India I | U.S.A. II | I—II |
| Major Process Equipment | 600 | 600 | — |
| Ocean Freight & Insurance | 60 | — | 60 |
| Import Duty | 130 | — | 130 |
| Installation Costs | 90 | 90 | — |
| Process Piping | 260 | 210 | 50 |
| Instrumentation | 130 | 100 | 30 |
| Building & Structures | 280 | 280 | — |
| Outside Battery Limits Auxiliaries & other supporting facilities | 680 | 340 | 340 |
| Engineering & Construction | 850 | 570 | 280 |
| Corporate Overhead Financing & Special Taxation | 120 | 70 | 50 |
| Total | 3200 | 2260 | 940 |

[Dr. A. K. Pal, Economic Times, Sept. 17, 1966]

TABLE 2—Operating Cost for Complex Fertilizer Factory—India and U.S.A.

| Item | Rs. per tonne of Plant Food (N+P) | | |
|---|---|---|---|
| | India I | U.S.A. II | I-II |
| Raw Materials: | | | |
| Naphtha | 85 | 70 | 15 |
| Sulphur | 211 | 115 | 96 |
| Rock Phosphate | 315 | 123 | 192 |
| Operating Materials: | | | |
| Catalysts & Chemicals | 27 | 22 | 5 |
| Bags | 102 | 56 | 46 |
| Miscellaneous Supplies | 22 | 15 | 7 |
| Wages, Salaries & Benefits | 60 | 210 | −150 |
| Utilities: | | | |
| Power | 133 | 100 | 33 |
| Fuel | 45 | 45 | — |
| Water | 7 | 7 | — |
| Maintenance Materials | 60 | 55 | 5 |
| Taxes & Insurance | 14 | 7 | 7 |
| Rental, Misc. Services | 3 | 3 | — |
| Depreciation | 213 | 150 | 63 |
| Corporate Overhead | 50 | 75 | −25 |
| Interest & Financing charges | 150 | 90 | 60 |
| Total | 1497 | 1143 | 354 |

[Dr. A. K. Pal, Economic Times, Sept. 17, 1966]

TABLE 3—Production of Pesticides

| | Capacity sanctioned | Current production | Capacity under negotiation |
|---|---|---|---|
| *Chlorinated Hydrocarbons* | | | |
| BHC, including lindane | 10,700(3)* | 10,000 | 38,100(13) |
| DDT | 4,200(2) | 2,630 | 3,000(1) |
| Toxaphene | 250(1) | 5 | — |
| Endrin | — | — | 1,000(1) |
| *Organo Phosphatics* | | | |
| Parathion | 700(2) | 5 | 2,500(2) |
| Malathion | 1,000(2) | 750 | 1,100(2) |
| Dimethioate | 220(1) | 5 | 780(1) |
| Others | — | — | 5,362(5) |
| *Carbamates* | | | |
| Carbaryl | — | — | 7,000(2) |
| *Thiocarbamates* | | | |
| Zineb ziram | 2,500(2) | 1,600 | 2,624(4) |
| Sulphur (dust, wettable) | 6,500 | 6,000 | — |
| Organo mercurial salts | 111 | 15 | — |
| Organic seed dressers (Thiram) | 300(1) | 80 | 1,254(4) |
| *Copper salts* | | | |
| Copper oxychloride | 2,284(4) | 1,500 | — |
| Copper sulphate | 5,250(9) | 5,200 | — |
| *Rodenticides* | | | |
| Zinc phosphide | 300(3) | 300 | 150(1) |
| Coumarin compounds | 50(2) | 20 | — |
| *Fumigants* | | | |
| EDB, methyl bromide, ED/CT mixture, Aluminium phosphide | 5,000(5) | 50 | 300(1) |
| *Weedicides* | | | |
| 2, 4-D, 2, 4, 5-T, etc. | 100(1) | 60 | 4,200(5) |

*Figures in parentheses indicate the number of plants/schemes.

[Eastern Economist, Annual Number 1968, (Dec. 29, 1967), 1191]

TABLE 4—OVERALL ANNUAL NEEDS OF PESTICIDES

(Tonnes)

| Pesticides | NCAER Estimate | Government's Estimate | |
|---|---|---|---|
| | Gross Coverage 282 million hectares | Gross Coverage 172 million hectares | Gross Coverage 85 million hectares |
| BHC | 86,527 | 40,000 | 27,200 |
| DDT | 9,908 | 10,000 | 2,400 |
| Endrin | 7,333 | 3,800 | 2,530 |
| Aldrin | 7,195 | 600 | N.A. |
| Dieldrin | 1,039 | N.A. | N.A. |
| Lindane | 24,222 | 1,600 | 1,600 |
| Malathion | 4,748 | 2,000 | 3,600 |
| Parathion | 8,709 | 2,400 | 2,330 |
| HETP | 218 | N.A. | N.A. |
| Carbaryl | 25,212 | N.A. | 5,930 |
| Thiocarbamate | 12,606 | 2,800 | 5,300 |
| Copper oxychloride | 27,525 | 6,000 | 3,900 |
| Sulphur | 1,40,295 | 10,800 | 5,870 |
| Mercury | 722 | 120 | 50 |
| Antibiotics | 1,759 | N.A. | 3,410 |
| Zinc phosphide | 720 | 2,480 | 273 |
| Methyl bromide | 450 | 300 | 300 |
| Ethylene dibromide | 150 | 250 | 100 |
| EDCT (3:1) | 900 | 9,500 | 600 |
| 2, 4-D, 2, 4, 5-T, MCPA, etc. | 4,500 | 14,500 | 3,180 |

N.A.=Not available.

*Report of the Working Group for the Formulation of the Fourth Five-Year Plan Proposals on Plant Protection, Ministry of Food and Agriculture, Department of Agriculture, Government of India, New Delhi, 1965, pp. 52 and 74.

[Eastern Economist, Annual Number 1968, (Dec. 29, 1967) 1194]

TABLE 5—RISE IN PRICES OF VARIOUS TYPES OF FERTILIZERS

| | Prices prior to April 1, 1967 | Current prices |
|---|---|---|
| | Rs. | Rs. |
| I. POOL FERTILIZERS: | | |
| Ammonium Sulphate 50 kg. bags | 416.00 | 503.00 |
| Ammonium Sulphate Nitrate | 515.00 | 577.00 |
| Calcium Ammonium Nitrate (20.5%) | 365.00 | 385.00 |
| Ammonium Phosphate (20-20-0) | 660.00 | 738.00 |
| Urea | 680.00 | 840.00 |
| Calcium Ammonium Nitrate (26%) | 405.00 | 455.00 |
| Di-Ammonium Phosphate (18-46-0) | 830.00 | 1,000.00 |
| Ammonium Chloride | 445.00 | 450.00 |
| II. NON-POOL FERTILIZERS: | | |
| A. *Superphosphate* | | |
| For port factories in eastern region (Calcutta port) | 256.48 | 308.33 |
| For port factories in other regions | 249.39 | 300.95 |
| For non-port factories: | | |
| Adarsh Chemicals & Fertilizers, Udhna (Gujarat) | 259.34 | 311.11 |
| Alembic Chem. Co. Ltd., Baroda | 265.59 | 317.35 |
| Ralli Chemicals Ltd., Magarwara (Maharashtra) | 383.01 | 335.04 |
| DCM Chemical Works, Delhi | 285.08 | 337.82 |
| West Indian Chemicals, Poona, Mundhwa | 259.34 | 317.44 |
| Dharamsi Morarji Chemical Co. Ltd., Kumhari, MP. | 265.99 | 319.00 |
| Andhra Fertilizers, Tadepalle | 265.13 | 317.82 |
| Associated Industries (Assam) Ltd., Chandrapur | 307.22 | 348.19 |
| Bihar State Superphosphate Factory, Sindri | 270.98 | 323.06 |
| Mysore Chemicals & Fertilizers, Belagula | 275.49 | 327.40 |
| B. *Potashic Fertilizers* | | |
| Export prices for muriate of potash (60% 'K') | 305.00 | 383.00 |
| Export prices for muriate of potash (50% 'K') | 250.00 | 315.00 |
| Ex-godown prices for muriate of potash (60% 'K') | 314.00 | 392.00 |
| Ex-godown prices for muriate of potash (50% 'K') | 259.00 | 324.00 |

[Eastern Economist, Annual Number 1968 (Dec. 29, 1967) 1188]

## TABLE 6—NITROGEN PROGRAMME

| | |
|---|---|
| 1. Existing Capacity | |
| *Public Sector*: | |
| Sindri | 117,000 |
| Nangal | 80,000 |
| Trombay | 90,000 |
| Rourkela | 120,000 |
| FACT, Alwaye | 70,000 |
| Neyveli | 70,000 |
| Gorakhpur | 80,000 |
| Namrup | 45,000 |
| Belagula | 1,300 |
| By-product from Coke Oven plants | 20,000 |
| | 693,300 |
| *Private Sector*: | |
| Ennore | 8,000 |
| Varanasi | 10,000 |
| Visakhapatnam | 80,000 |
| Ennore Expansion | 8,000 |
| Gujarat | 96,000 |
| | 202,000 |
| Total | 895,300 |
| 2. Projects due for completion in 1969-70 | |
| *Public Sector*: | |
| Durgapur | 152,000 |
| Cochin | 152,000 |
| FACT—4th stage | 22,000 |
| | 326,000 |
| *Private Sector*: | |
| D.C.M. | 130,000 |
| Gujarat Expansion | 120,000 |
| | 250,000 |
| Total | 576,000 |
| 3. Firm projects due for completion in 1970-71 | |
| *Public Sector*: | |
| Madras | 190,000 |
| Namrup II | 152,000 |
| Barauni | 152,000 |
| | 494.000 |
| *Private Sector*: | |
| Kanpur | 200,000 |
| Total | 694,000 |
| 4. Projects approved but work yet to start—likely to be completed by 1970-71 and 1971-72 | |
| *Public Sector*: | |
| Trombay Expansion | 229,000 |
| *Private Sector*: | |
| Goa | 160,000 |
| Mangalore | 240,000 |
| Haldia | 142,000 |
| | 542,000 |
| Total | 771,000 |
| 5. New Projects—expected to be completed in 1970-71 and 1971-72. | |
| *Public Sector*: | |
| Kandia (Co-operative) | 215,000 |
| *Private Sector*: | |
| Modi (Ghaziabad) | 160,000 |
| Total | 375,000 |

### SUMMARY

| | |
|---|---|
| 1. Existing | 895,300 Tonnes |
| 2. 1969-70 Additional | 576,000 ,, |
| 3. 1970-71 Additional | 694,000 ,, |
| 4. 1970-71 and 1971-72 Additional | 771,000 ,, |
| 5. 1970-71 and 1971-72 Additional | 375,000 ,, |
| Total | 3,331,300 Tonnes |

*Note:* If Mirzapur project and the Visakhapatnam both first and second phase expansions also go on stream by 1972-73, the total capacity for producing nitrogenous fertilizers will go up to about 3.55 million tonnes.

[Eastern Economist, Annual Number 1968 (Dec. 29, 1967) 1178]

TABLE 7—PHOSPHATE PROGRAMME

| | $P_2O_5$ (Figures in tonnes) |
|---|---|
| 1. Capacity as on September 1, 1967 | 286,830 |
| 2. Projects due for completion in 1967-68 | |
| (*a*) West India Chemicals | 6,600 |
| (*b*) Metal Corporation of India | 12,700 |
| (*c*) Alembic Chemical Works | 1,680 |
| (*d*) J. K. Cotton, Kanpur | 6,770 |
| (*e*) Bharat Fertilizer Industries Ltd. | 3,750 |
| (*f*) Phosphate Co. Ltd., Calcutta | 3,488 |
| (*g*) Dharamsi Morarji | 13,000 |
| (*h*) Visakhapatnam | 73,000 |
| (*i*) By-product Di-Calcium Phosphate | 11,140 |
| | 132,128 |
| 3. Projects due for completion in 1969-70 | |
| (*a*) FACT IV Stage | 9,200 |
| (*b*) Kota (DCM) | 30,000 |
| (*c*) Maharashtra Agro-Industries Corpn., Bombay | 6,680 |
| | 45,880 |
| 4. Projects sanctioned and due for completion in 1970-71 | |
| (*a*) Madras | 85,000 |
| (*b*) Trombay | 124,000 |
| (*c*) Haldia | 79,000 |
| (*d*) Mangalore | 90,000 |
| | 378,000 |
| 5. Projects likely to be taken up and due for completion in 1970-71/1971-72 | |
| (*a*) Sindri (TSP) | 156,000 |
| (*b*) Kandla (Co-op.) | 127,000 |
| | 283,000 |
| 6. Khetri Project 100,000 tonnes will be on stream in 1971-72. | |
| 7. Direct Application of powdered rockphosphate 100,000 tonnes $P_2O_5$ by 1970-71. | |

SUMMARY

| | | |
|---|---|---|
| 1. Capacity on September 1, 1967 | | 286,830 |
| 2. 1967-68 | Additional | 132,128 |
| 3. 1969-70 | Additional | 45,880 |
| 4. 1970-71 | Additional | 378,000 |
| 5. 1970-71 & 1971-72 | Additional | 283,000 |
| 6. 1970-71 | Direct application | 100,000 |
| 7. 1971-72 | Additional | 100,000 |
| | | 1,326,000* |

*Does not include expansion of Visakhapatnam project. Under the first phase expansion of this plant, nearly 15,000 tonnes capacity will be added through the process of removing bottlenecks.

[Eastern Economist, Annual Number, 1968 (December 29, 1967), 1179]

TABLE 8—AREA AND PRODUCTION OF AGRICULTURAL COMMODITIES

(1950-51—1962-63)

| Commodity | 1950-51 (a) | | 1955-56 | | 1960-61 | | 1961-62 | | 1962-63 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Area (Hectares) | Production (Tonnes) | Area (Hectares) | Production (Tonnes) | Area (Hectares) | Production (Tonnes) | Area (Hectares) | Production (Tonnes) | Area (Hectares) | Production (Tonnes) |
| FOODGRAINS (a) | | | | | | | | | | |
| CEREALS | | | | | | | | | | |
| 1. Rice | 30,519 | 23,542 | 31,521 | 27,557 | 34,128 | 34,574 | 34,694 | 35,663 | 34,934 | 31,914 |
| 2. Wheat | 9,758 | 6,391 | 12,367 | 8,760 | 12,927 | 10,997 | 13,570 | 12,072 | 13,657 | 10,829 |
| 3. Jowar | 15,513 | 5,870 | 17,362 | 6,726 | 18,412 | 9,814 | 18,249 | 8,029 | 18,021 | 9,621 |
| 4. Bajra | 9,259 | 2,835 | 11,338 | 3,428 | 11,469 | 3,283 | 11,278 | 3,645 | 10,800 | 3,892 |
| 5. Maize | 3,262 | 2,046 | 3,696 | 2,602 | 4,407 | 4,080 | 4,507 | 4,312 | 4,607 | 4,578 |
| 6. Ragi | 2,206 | 1,544 | 2,307 | 1,846 | 2,515 | 1,838 | 2,511 | 2,030 | 2,316 | 1,891 |
| 7. Barley | 3,181 | 2,251 | 3,418 | 2,816 | 3,205 | 2,819 | 3,312 | 3,150 | 3,022 | 2,423 |
| 8. Small millets | 5,415 | 2,278 | 5,335 | 2,070 | 4,955 | 1,909 | 4,868 | 2,050 | 4,693 | 1,860 |
| Total cereals | 79,113 | 46,757 | 87,344 | 55,805 | 92,018 | 69,314 | 92,989 | 70,951 | 92,050 | 67,008 |
| PULSES | | | | | | | | | | |
| 9. Gram | 8,295 | 3,726 | 9,779 | 5,418 | 9,276 | 6,250 | 9,566 | 5,785 | 9,177 | 5,343 |
| 10. Other pulses | 11,872 | 4,433 | 13,437 | 5,627 | 14,287 | 6,454 | 14,677 | 5,970 | 14,782 | 6,097 |
| Total pulses | 20,167 | 8,159 | 23,216 | 11,045 | 23,563 | 12,704 | 24,243 | 11,755 | 23,959 | 11,440 |
| Total foodgrains (cereals & pulses) | 99,280 | 54,916 | 110,560 | 66,850 | 115,581 | 82,018 | 117,232 | 82,760 | 116,009 | 78,448 |
| NON-FOODGRAINS | | | | | | | | | | |
| 11. Sugarcane (b) | 1,707 | 5,705 | 1,847 | 6,075 | 2,415 | 11,141 | 2,445 | 10,563 | 2,280 | 9,554 |
| 12. Oilseeds | 10,727 | 5,158 | 12,085 | 5,734 | 13,770 | 6,982 | 14,772 | 7,284 | 14,794 | 7,113 |
| (*i*) Groundnut (nuts in shell) | 4,494 | 3,481 | 5,133 | 3,862 | 6,463 | 4,812 | 6,889 | 4,994 | 6,834 | 4,821 |
| (*ii*) Rape and mustard | 2,071 | 762 | 2,556 | 860 | 2,883 | 1,347 | 3,168 | 1,346 | 3,108 | 1,294 |
| (*iii*) Sesamum | 2,204 | 445 | 2,293 | 467 | 2,169 | 318 | 2,252 | 372 | 2,488 | 464 |
| (*iv*) Linseed | 1,403 | 367 | 1,529 | 420 | 1,789 | 398 | 1,977 | 463 | 1,899 | 433 |
| (*v*) Castor seed | 555 | 103 | 574 | 125 | 466 | 107 | 486 | 109 | 435 | 101 |
| 13. Cotton (Lint) (c) | 5,882 | 2,875 | 8,086 | 3,949 | 7,610 | 5,293 | 7,978 | 4,581 | 7,845 | 5,309 |
| 14. Jute (c) | 571 | 3,309 | 704 | 4,232 | 629 | 4,134 | 917 | 6,358 | 851 | 5,449 |
| 15. Mesta (c) | — | — | 231 | 1,162 | 274 | 1,129 | 425 | 1,878 | 379 | 1,697 |
| 16. Tea | 317 | 279 | 321 | 308 | 331 | 321 | 333 | 354 | 334 | 347 |
| 17. Coffee | 93 | 19 | 103 | 35 | 120 | 68 | 125 | 46 | 126 | 56 |
| 18. Rubber | 69 | 16 | 84 | 24 | 130 | 26 | 141 | 27 | 146 | 32 |
| 19. Tobacco | 357 | 261 | 410 | 303 | 401 | 307 | 418 | 339 | 416 | 366 |

(*a*) Data regarding foodgrains relate to 1949-50 which was the base year in respect of foodgrains for the first five year plan.
(*b*) Yield in terms of gur.
(*c*) Production in thousand bales of 180 kilograms each.

[Eastern Economist, Annual Number, 1968, (Dec. 29, 1967), 1310]

## Area and Production of Agricultural Commodities—*(Contd.)*

(1963-64—1966-67)

| Commodity | 1963-64 | | 1964-65 | | 1965-66 | | 1966-67* | |
|---|---|---|---|---|---|---|---|---|
| | Area (Hectares) | Production (Tonnes) | Area (Hectares) | Production (Tonnes) | Area (Hectares) | Production (Tonnes) | Area (Hectares) | Productin (Tonneso) |
| FOODGRAINS | | | | | | | | |
| CEREALS | | | | | | | | |
| 1. Rice | 35,622 | 36,889 | 36,364 | 39,034 | 35,022 | 30,614 | 35,598 | 30,440 |
| 2. Wheat | 13,496 | 9,861 | 13,460 | 12,290 | 12,798 | 10,720 | 13,135 | 11,528 |
| 3. Jowar | 17,956 | 9,135 | 17,938 | 9,749 | 17,181 | 7,492 | 18,001 | 8,944 |
| 4. Bajra | 10,785 | 3,734 | 11,726 | 4,454 | 11,428 | 3,598 | 12,458 | 4,503 |
| 5. Maize | 4,584 | 4,553 | 4,618 | 4,658 | 4,683 | 4,632 | 5,061 | 4,991 |
| 6. Ragi | 2,400 | 1,962 | 2,437 | 1,898 | 2,198 | 1,305 | 2,374 | 1,600 |
| 7. Barley | 2,775 | 2,037 | 2,684 | 2,523 | 2,551 | 2,284 | 2,859 | 2,449 |
| 8. Small millets | 4,580 | 2,017 | 4,513 | 1,952 | 4,331 | 1,602 | 4,720 | 1,671 |
| Total cereals | 92,198 | 70,188 | 93,741 | 76,558 | 90,192 | 62,247 | 94,206 | 66,126 |
| 9. Gram | 9,376 | 4,499 | 8,896 | 5,785 | 7,849 | 4,442 | 8,015 | 3,612 |
| 10. Other pulses | 14,679 | 5,556 | 14,897 | 6,652 | 13,601 | 5,575 | 14,243 | — |
| Total pulses | 24,055 | 10,055 | 23,793 | 12,437 | 21,450 | 10,017 | 22,258 | — |
| Total foodgrains (cereals & pulses) | 116,253 | 80,243 | 117,533 | 88,996 | 111,642 | 72,264 | 116,484 | — |
| NON-FOODGRAINS | | | | | | | | |
| 11. Sugarcane (b) | 2,257 | 10,596 | 2,526 | 12,031 | 2,749 | 11,830 | 2,382 | — |
| 12. Oilseeds | 14,710 | 7,038 | 15,110 | 8,458 | 14,639 | 6,097 | 14,852 | 6,489 |
| (*i*) Groundnut (nuts in shell) | 6,809 | 5,215 | 7,216 | 5,888 | 7,171 | 4,022 | 7,251 | 4,485 |
| (*ii*) Rape and mustard | 3,023 | 903 | 2,881 | 1,466 | 2,891 | 1,268 | 2,995 | 1,246 |
| (*iii*) Sesamum | 2,395 | 439 | 2,513 | 493 | 2,456 | 406 | 2,480 | 425 |
| (*iv*) Linseed | 2,006 | 379 | 2,059 | 503 | 1,764 | 329 | 1,526 | 335 |
| (*v*) Castor seed | 477 | 102 | 440 | 108 | 356 | 71 | 412 | 81 |
| 13. Cotton (Lint) (c) | 8,160 | 5,494 | 8,271 | 5,664 | 7,827 | 4,708 | 7,834 | 4,931 |
| 14. Jute (c) | 868 | 6,185 | 838 | 6,020 | 756 | 4,471 | 798 | 5,348 |
| 15. Mesta (c) | 393 | 1,874 | 360 | 1,583 | 320 | 1,244 | 318 | 1,214 |
| 16. Tea | 334 | 346 | 338 | 372 | 342 | 365 | — | — |
| 17. Coffee | 129 | 69 | — | 61 | — | 60 | — | — |
| 18. Rubber | 153 | 37 | 155 | 46 | 165 | 51 | — | — |
| 19. Tobacco | 440 | 358 | 394 | 346 | 345 | 274 | 351 | — |

*Note:* (1) Figures relate to the agricultural year ending June. Item 16 refers to the calendar year i.e., figures for 1950-51 relate to 1950 and so on; however, area figures refer to the financial year ending March. Item 18 refers to the financial year ending March. (2) Figures for 1962-63, 1963-64 and 1964-65 are partially revised estimates while those for 1965-66 are final estimates. (3) In the case of jute 1965-66 is partially revised estimate. (b) Yield in terms of gur, (c) Poroduction in thousand bales of 180 kilograms each.

*Latest estimates available.

[Eastern Economist, Annual Number 1968 (Dec. 29, 1967), 1311]

# Appraisal of Scientific and Philosophical Concepts in Ancient India in the light of the Theory of Universal Wave

By

K. R. CHAKRAVORTY,

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

In this work the author makes an attempt to clarify some of the basic and elementary aspects of the theory of universal wave such as: limitation of perception relative to conception; true meaning of self-sufficient equilibrium concept of a perfectly isolated system; concept of dimensions and their magnitudes of size and intensity which are required for generating an equilibrium concept. That two opposite pairs of two opposite dimensions are required to make an equilibrium wave and the significance of an equation to represent the equilibrium concept have been clarified. The real meaning of dimensions as to what a fundamental dimension like energy is and what a derived one like matter is, as well as the function of their containing dimensions, like space and time, in generating the configuration have been explained.

Laws of evolution and dissolution, which determine equilibrium in an isolated concept, must assume tetrahedral significance in configuration. Deduction of matter, energy, time, space dimensional equation of equilibrium as $E/M = L^5/T^4$ has been further clarified. The resultant configuration of space, time, matter, and energy universe is one of equilibrium between two opposite component configurations: one for creation, the other for dissolution.

It has been shown that in the ultimate analysis, all universal phenomena and manifestations can be reduced to configurations due to space/time co-ordinates having only something of illusory nature of matter/energy significance in essence: all that we experience are only manipulations of space and time co-ordinates.

It has been shown that the definition of fundamental dimension in the present theory carries with it identical significance in the various essential attributes accorded to the fundamental or absolute namely, Purusa, Shiva, Param Brahman, Param Atman, Suddha Atman, Ananta Sayanam, Satchitananda etc. in the ancient philosophies such as Sankhyya, Puranas, Sruti, Smriti, Brahma Sutra, Veda, Manu Samhita etc. It has been also explained how the application of the principles of universal wave was made in ancient India to situations and events in various spheres and attitudes of life namely, concept of caste system, Astronomy, Astrology, Trigonometry, Mathematics, Ayurvedic system of medicine, methods of self-cultivation, and various attitudes and approaches in different philosophies etc.

In this work, identification of the geometrical aspects of the configuration of universal wave with the Jantras and Kundalis in Tantra philosophy, as employed in Tantric system of worship, has been exemplified. Analysis of the Jantras shows identical resultant geometrical concepts of equilibrium configuration of the universe between action and reaction of two opposite processes, namely creation and dissolution between opposite limits. That the existence of the universe is an equilibrium configuration established between its start as point concept as centre and ending up in the same concept at boundary has been explained. In between the equilibrium configuration, various dimensions with their magnitudes change between these two extreme opposite limits retaining tetrahedral structural significance.

The concept of equilibrium configuration is applicable to all kinds of universe, be it energy-matter inanimate universe or be it the spiritual universe of Atman and Indriya dimensions: equilibrium existence is due to oscillation of the component configurations between two opposite limits, namely a central point concept at start of evolution and dissolution in point concept at the boundary. Conventional law of periodic classification of elements as 2, 8+8, 18+18, 32+32 . . . has been examined in the light of law of Evolution as per dictates of Universal Wave as well as the Jantras (which are identical) which reveal that the Law of Evolution of numerical magnitudes of elements in heterogeneous system should be 2+2, 8+8, 18+18, 32+32 . . . With the help of space-time co-ordinates in association with statistical probability aspect, it has been explained why the evolved universe would look

egg-shaped as Brahmanda and not Brahma Golak (as sphere). In the created finite universe, all the created beings experience the phenomenal manifestation of the universe through their derived dimensions between these opposite limits remaining always in association with fundamental dimension.

By taking the configuration of the universal wave, discussion, which automatically leads to deduction of what true ideology of life and civilisation should be, has been analysed. As against the true ideology, actual situations which one finds in the present world have been critically examined. It has been shown that true ideology as deduced from the universal law does not exist these days: all our approaches and attitudes are opposite or contrary to real truth. Mahatma Gandhi's ideology of Non-violence, Ahimsa of Buddha, Mahabira, Christ and so on have been identified with the true ideology deduced from the theory of universal wave.

Ideology to attain supreme self-happiness through self-sacrifice or renunciation for the benefit of others does not exist in attitudes to life these days. Our whole and sole attitude and approach is towards getting physical self comfort at the cost of others; which, in actual practice, is the dominant attitude in individual, national and international spheres. On this background analysis, true ideology of culture and civilisation has been enunciated.

## I. Significance of Universal Wave and the Universal Law

Since the publication of the theory of the universal wave of "The energy field of the universe and atom", it appears and it is quite likely also, that there has been considerable difficulty in understanding the theory in perspective. The main reason for such difficulties is the inadequacy of conventional terminology and language which had to be employed to express the concepts of the theory.

### Limitation of perception relative to conception

One of the postulates in the theory is that a total concept can be only partly physically realised in practice, in this finite universe. This would apply to all phenomena which involve two evolutionary aspects—the first, involving a certain idea, ideology or concept which can be realised in thinking and the second involving realisation of such concept in perception through objective or symbolic presentations or through configuration, in order to render it perceivable to others through physical means, whether they be animate means such as the various physical organs of the animal being or inanimate means like apparatus, instruments etc. The degree of realisation of the first aspect can only be in part. This is the basic truth about all facets of universal manifestations.

Human faculties have two main properties—one physical and the other mental. Thoughts yield concept, whereas perception occurs through the physical faculties. Conception covers wider fields and aspects than what physical perception does. Let us imagine an inflated football with 100 points of positions uniformly printed on the spherical surface. In conception it is possible to imagine it and one can have a mental picture of the same. But when the football is brought within the human perception of vision at correct or most optimum equilibrium position as we are situated, one can only perceive a maximum of 1/2 i.e. only points imprinted on one hemisphere of the ball can be seen through visual organ and the other half remains unseen. Many such illustrative cases could be cited and ultimately the same conclusion would be arrived at in regard to the limitation of perception viz-a-viz conception. At equilibrium between conception and perception, a balance would be established as illustrated in the case of the football with maximum half of conception. Out of the total concept, at best we can directly perceive only as positive experience and the other half as uncertain or imaginary. The balanced max. equilibrium ratio of the certainty and uncertainty would thus be unity. But the equilibrium perception may vary; for example at an appropriate range of our vision one can have only maximum equilibrium perception of 50%. But if the ball undergoes variation in position and would be far-away from the observer, the positive perception diminishes and the portion which is not perceived increases. Similarly, if the ball is brought too close to the observer it undergoes a blurred effect of diminishing positive perception.

Another illustrative example is the case of the Moon. Half of the Moon's surface is always lit with Sun's light whereas the other half is perpetually in darkness. But this 50% of the bright side is seen only at the time of the full Moon from the Earth but at the time of Amavashya or new moon no part of the surface lit by the Sun is visible from the Earth. In concept, Moon is always half bright and half dark but in perception, with variation of position, its actual equilibrium balance of brightness divided by darkness varies from unity to nil after approximately 15 days. This repeats periodically at the full Moon, our perception of the Moon corresponds to its equilibrium ratio of brightness to darkness as unity. At Amavashya, our perception of Moon is nil, i.e. ratio of brightness to darkness is nil. Moon, however, has been always maintaining equilibrium ratio of brightness and darkness as unity, while our potential of perception varies. The potential of perception and the equilibrium ratio of certainty to uncertainty, therefore, depends on the varying positions in a field of observation. A total concept is constant but perception

varies. The equilibrium perception, i.e. the ratio of positive to negative, certainty to uncertainty, or such other properties would, therefore, depend on the position in the field of observation and its variability relative to the observer. Thus to get the truth or fact of existence in this universe requires potential (or capacity) to perceive the facts in full. Experiments alone cannot do that; utmost they can reveal a part, which also is likely to be distorted. Power or potential of perception should be the most important apparatus, aided, of course, by conception or knowledge of our relative existence to know the fundamental facts about the universe. Scientific apparatus like computers by themselves cannot do that.

In dynamic geometry, the ratio of certainty and uncertainty in relation to various manifestations and the resultant geometrical configuration describing them should thus play most significant role in our search for the fundamental scientific facts of the universe. The above illustrations demonstrate that the maximum that can be known through material apparatus is a maximum of half of what can be known through mental or conceptual apparatus.*

The above illustrations lead us to one of the most important basic postulates of the law of universe. The law is: "A total concept of truth cannot be realised in full in practice through means of physical perception. The actual or true concept of the universe, when it will be realised in practice is realised only within the limitation of reality. The concept of the universe as a whole is one of imagination." When that would be realised or attempted to be analysed objectively and quantitatively, it must be through finite means.

The entire picture of a 'concept' can never be realised to the fullest extent as concrete object through limited physical means. (These postulates are also applicable to the various basic concepts involved in the theory of universal spherical wave of energy field.) In Part-I+, the basic ideas were attempted to be explained through spherical surface configurations termed as equipotential surfaces) at radial distances between the centre and the boundary of the spherical wave. The variations of the magnitudes of dimensions which constitute the spherical wave occur through these states between the two extreme states of centre and boundary; applying this principle, many outstanding physical phenomena in the universal context were explained. In this work the only mathematical tool employed is conventional dimensional analysis, in which energy was incorporated as the fundamental dimension. In Part II, further clarifications of various postulates were made and they were applied to explain other outstanding physical phenomena by adopting various configurations incorporating tetrahedral evolutionary concept of configuration. Further clarification of the postulates of the theory was attempted in the Paper "Introduction to Understanding of the Theory of Universal Spherical Wave of the 'Energy Field of the Universe and Atom': *Technology*, 1966, **3** (2)" and Geometry of Space Time Configuration: The postulates in the theory were attempted to be explained in several ways: by dimensional analysis, by conventional geometrical configurations as well as by numerical presentations. Even then, in spite of the many approaches and efforts that have been made to project the basic postulates in understandable form to the scientists, it appears that, due to the unorthodoxy and unconventional approach and nature of basic thoughts involved in these postulates, difficulties remain in the way of their understanding by the readers. This perhaps could not be avoided since one of the basic postultes in the theory, indicated in the above, necessarily implies the inevitability of such a situation.

**Description of a self-sufficient concept capable of independent existence in equilibrium**

Coming to the concept of the universal spherical wave, one of the most important enquiries relates to the understanding of the concept of a manifestation which is capable of independent existence in isolation and which maintains equilibrium due to factors which exist within the manifestation itself so that no reference whatsoever is required elsewhere outside the manifestation for explanation of events occurring within its constitution. This means that the isolated manifestation, which in this theory is the universal evolutionary spherical wave, is constituted of certain dimensions whose mode of variation in their relative magnitudes maintains equilibrium within the wave without reference to any thing outside its configuration. All changes occurring within the manifestation are due to factors which exist within and nowhere else. This isolated self-sufficient evolutionary spherical wave concept of manifestation is similar in concept to the isolated system in the science of Thermodynamics. Though the latter isolated system is no doubt assumed as a state in isolation, is situated in a surrounding space or in an atmosphere which is positive (which is not 'nothing') with which it is in equilibrium but there is no exchange of matter or energy as heat between the two. Thermodynamical isolated system presumes that although the system in isolation may exist within a positive surrounding, any change

*(Reference Geometry of space time configuration Technology,Vol 4 No. 1 & 2, 1967.

+Technology, 1964, 1(3 Suppl.).

which may occur within the system has no effect on the surrounding. The thermodynamical isolated system is not a concept which, while maintaining equilibrium within it by factors or influences or dimensions existing within due to their variations, excludes the simultaneous effect on the surrounding which is not 'nothing' but something positive. Take for example the case of adiabatic expansion or contraction of a volume of a gas as a thermodynamical isolated system. The concept of isolated existence in the concept of configuration of universal spherical wave at equilibrium, however, is different from the concept isolated system in thermodynamics to the extent that the entire existence of the concept is within the spherical wave beyond which there is nothing and there is no simultaneous existence of anything else. The perfect concept of an isolated system cannot be within a surrounding containing something.

The universal spherical wave concept is one in which everything conceivable exists within the wave which is situated in isolation in self-sufficient equilibrium in a surrounding medium containing nothing or nil. This basic aspect of the theory must first be understood. Knowing the proper constitutents which in the theory are called dimensions, and knowing nature of variation of their relative magnitudes the concept is developed as an equilibrium state of existence by the variation of their associated properties, the concept assume the configuration of universal ave surrounded by nothing.

Consider the concept of a tree and what is apparently seen and known about it. Its existence from birth to death starts with seed as the cause and ends up with the seed for future evolution of the tree. As far as the tree is concerned, the evolutionary wave would describe it from the beginning to the end. Correctly speaking, the tree is not strictly an isolated system of existence because it thrives in the atmosphere surrounding it. The concept of 'tree' cannot thrive without the surrounding atmosphere that exists between its start as seed and its end also as seed. While taking the whole picutre, as far as the concept of tree is concerned, as it is, it cannot be a case of a truely isolated system of equilibrium, though it can be compared to a thermodynamical isolated system. The only example of theoretical concept of isolated equilibrium is the existence of the universe as such. The inanimate universe is an isolated concept within which various dimensions constituting it viz. space, time, energy and matter, by their relative variations of magnitudes and their properties of variabilities etc. maintain equilibrium states within this isolated system. Beyond the universe, simultaneoulsy nothing exists. The universe, as it is, is an isolated system of self-sufficient equilibrium existence of constitutent dimensions maintaining its configuration as a universal spherical wave, in a surrounding medium of nothingness. The term "isolated system" corresponds to "finite entity" in significance.

With this description of a self-sufficient equilibrium concept capable of independent existence, one can proceed to the next basic postulate of the theory which states that an isolated system of concept existing in equilibrium must for its generation or evolution, have a start, which again must start from some cause. To understand this, one can imagine a situation of nothingness (although it is true that such a situation of nothingness cannot be comprehended by human faculties but can possibly be conceived in imagination). If such an isolated concept would be evolved or generated or created from out of a background situation of nothingness, it cannot occur without a cause. Like the seed for a tree such a seed for an isolated concept of manifestation for its generation must have a cause and that cause in this theory has been termed as the fundamental dimension. Before the manifestation makes the start, the fundamental dimension was in a state of existence which was beyond the concept of finite manifestation perceptible to human faculties. In other words, the human faculties, which are capable of perceiving or conceiving or appreciating what is within the finite manifestation, cannot comprehend a prior state of fundamental dimension which subsequently has caused the manifestation. In that prior state, before the finite manifestation, the fundamental dimension is an incomprehensible state which is abstract and cannot be defined. The fundamental dimension at that state was the only one as the cause of the subsequent manifestation and was not associated with any other constituent dimension; because, at that state of abstract existence, no other dimension, even to the least degree of association, could have been associated with it, since the association of any other dimension with the fundamental, even in least proportion become the starting point of the finite manifestation. Since, according to the postulates of the theory when the fundamental from its abstract state of existence, associates with any other dimension, that would be the starting point of the finite manifestation and that also would be starting point of association of various properties of the fundamental dimension itself with those of the derived dimensions for the start of the finite manifestation. The latter will assume a configuration in association with other containing or congnisable dimensions of the fundamental and the derived and exhibit itself assuming an equilibrium configuration conceivable to human faculties and intellect.

A state of infinite purity is also an abstract state in comprehension. After creation, the fundamental dimension exists in combination and association with other dimensions. Its proportion in the whole is diminished. Before creation, the fundamental in its abstract state is not associated with any other dimension. Therefore, it was in its full proportion of its whole and it could only be described by the term 'infinite purity'. When a dimension, in its abstrcact state has not taken any configuration of finite manifestation in association any other dimension it is in a state of infinite purity. In the created manifestation, the fundamental degenerates in its purity by virtue of its association with other dimension constituting the manifestation as an objective one.

When this concept is applied to the manifestation of the finite inanimate universe, the fundamental dimension must be energy and not matter. Matter is the derived dimension. Energy in association with matter manifests the universe, space and time which are the containing dimensions of the fundamental and derived dimensions respectively in association with variability can give the finite manifestation a shape or form in which the observed universal characteristics are perceived, experienced and seen by human faculties and intelligence.

From this we come to an important property of the fundamental dimension: when the fundamental dimension associates with other dimension, it forms a finite manifestation of tetrahedral configuration. But the enquiry now is: before the manifestation when the fundamental dimension was not associated with any others, then what was the true nature of that dimension and its configuration ? The answer to this is not very difficult because when a dimension is not associated with any other it must be in a state of purest existence as far as it itself is concerned. Therefore, the fundamental dimension, prior to its creation of finite manifestation, is a concept of its existence in its infinite purity. What would this again mean? A dimension in its infinitely pure state means that there is no associated diluent to reduce its intensity or purity. Therefore, it is actually a state of the fundamental dimension as infinitely pure state of existence. It can also be called a state of existence of the fundamental dimension in its infinite intensity. All these terms are, more or less synonymous and should be understood in proper perspective.

Let us now analyse what the configuration of fundamental at its finite purity and intensity would be. Since the fundamental from this state assumes finite configuration of regular tetrahedron of least magnitude with centre possessing finite highest of fundamental and the 4 positions possessing least of derived when it becomes a finite manifestation, it can be concluded that fundamental of infinite purity also has tetrahedral configuration of nil magnitude which is imaginary and the infinite fundamental occupies the imaginary centre of an imaginary regular tetrahedral configuration in which the four imaginary positions contain nothing.

We shall now come to the next basic postulate of the theory. Finite manifestation is evolved due to a fundamental dimension as the cause. The fundamental dimension causes the manifestation when it associates with another dimension such that the two dimensions are opposites in all respects. If the property of the fundamental is to act in one manner or one direction, the derived dimension, which by association with the fundamental creates the finite manifestation, must work in opposition to that of fundamental. Therefore, the finite manifestation is due to two opposite dimensions —one the fundamental and the other derived, both being opposite in all respects. The next point is that when the fundamental dimension, in association with the derived, starts creation of the manifestation, the fundamental dimension has always the property of 'expansion' and the derived has the opposite—the property of 'contraction'. If the fundamental creates emanation of space from a point of position, then the tendency of the derived would be to create a point of position in the created space. That means, its tendency would be to concentrate positions in space towards one point, whereas the tendency of fundamental would be to disperse the positions in space.

Apply this to the manifestation of the finite universe. Here the fundamental dimension is energy. The energy creates space and matter occupies a point of position in the created space. These two are the fundamental and derived dimensions. But the universal manifestation, as has been mentioned before, manifests itself and gives out its configuration by association with certain other containing dimensions with energy and matter. In this theory, space and time are the containing dimensions of energy and matter respectively. Since energy is the fundamental dimension, its property is expansive, i.e. it starts its manifestation emanating through a point of position and its direction is radial whereas the matter occupies a position in space configuration and undergoes a orbital course described by time. This is further explained as follows. The fundamental dimension energy starts with highest purity or highest intensity. In terms of space configuration, it signifies that, since space is the containing dimension of energy, the intensity of energy would be highest with least magnitude

of space containing it, i.e. magnitude of space associated with the fundamental in its abstract state of existence was associated with nil space. The finite manifestation of energy starts with least magnitude of space. As the energy emission takes place in the form of increasing magnitudes of space from a point of position, at the emanating point of position intensity of energy would correspondingly be less than infinity. Now the important question arises about the nature of the emission of energy as space from a point of position. Since we are considering its manifestation in the background of nothing, therefore, the possibility of its emission as space from the starting point should not have any particular preference for one or other direction. The space must emanate from the starting point of position in absolutely uniform isotropic directions. The postulates in the theory state that such emission of energy is regular tetrahedral. Energy with highest intensity, assumes the centre position of the regular tetrahedron and the matter positions associate with the tetrahedral four corner positions. Now imagine the starting point of position of energy creating space. At that state, the space configuration of least magnitude was associated. In the tetrahedral context, energy was occupying the centre position of the tetrahedron but with least magnitude of size of the tetrahedron and least magnitude of matter associated with energy; the matter dimensions, however, occupy the four corner positions of the tetrahedron. Occupation of the four corners of the tetrahedron by matter with its least intensity signifies the combination of matter of least intensity in association with highest intensity of energy at the starting point and combination has four probabilities to start with and while configuration in subsequent states increases in magnitude i.e. associated space configuration increases in magnitudes in radial direction, the matter intensity of the corner positions, associated with the factor called variability or motion or 'dynamicity' describes their course as orbit increases and intensity of energy in association decreases. When tetrahedral space configuration from least magnitudes increases its size of configuration the interspace between four matter positions occupying the corners of the tetrahedron increase in magnitude; the positions are varying during the course of expansion and describing spiral orbit. Thus the variation of magnitude of energy intensity, variation of intensity of matter, variation in the magnitude of size of space configuration of energy, variation of magnitude of size of time configuration of matter, all of them together, by their mode of variation, create an equilibrium situation giving rise to the concept of configuration of the universal sphrical wave. The starting position of emission of energy from its highest intensity creates increasing magnitude of space. The energy intensity, contained in it, decreases correspondingly. Thus when energy from the point of position in four increasing radial directions of the tetrahedron will emanate four tetrahedral positions of matter, which simultaneously vary in orbital directions relative to the radials, the positions must describe spiral course. The intensity of matter positions in the starting state in association with highest energy intensity was least. As the positions proceed radially further from the starting point, the magnitude of matter intensity of the positions increases till the tetrahedron will assume a magnitude of its configuration at which the four positions will assume a magnitude of radial space when the intensity of energy of the space and associated intensity of four matter positions are equal; further, the magnitude of radial space has increased to a state at which magnitude of orbital time configuration of four matter positions assume equality. This is the equality equilibrium state of the universal wave. At this state, the four positions of the tetrahedron have developed sufficiently high magnitude of variability such that, at that a constant radial distance from the centre at any instant (which is the magnitude of space), one position will be found which will give the appearance of spherical surface locus of probable presence of the four positions at any instant at that spherical surface ABCD.

It should be noted that up to this state the energy occupying the tetrahedral configuration and the matter magnitudes pertaining to the four corner positions belong to one tetrahedral configuration only, i.e. so far no matter significance associated with the positions have separated from the tetrahedral configuration of energy itself. The energy and matter thus were intimately associated with each other in the same configuration. Up to the equality equilibrium surface state, the magnitude of the tetrahedron has developed to the extent that the energy intensity in the developed space or energy distribution at

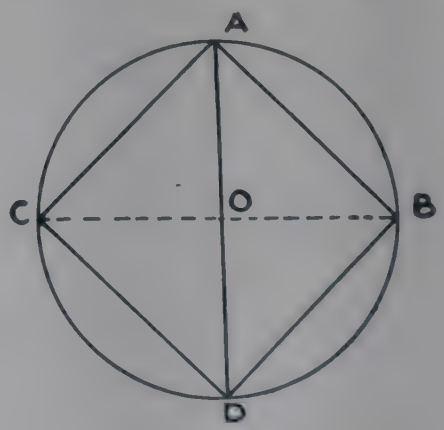



Fig. 1(a)

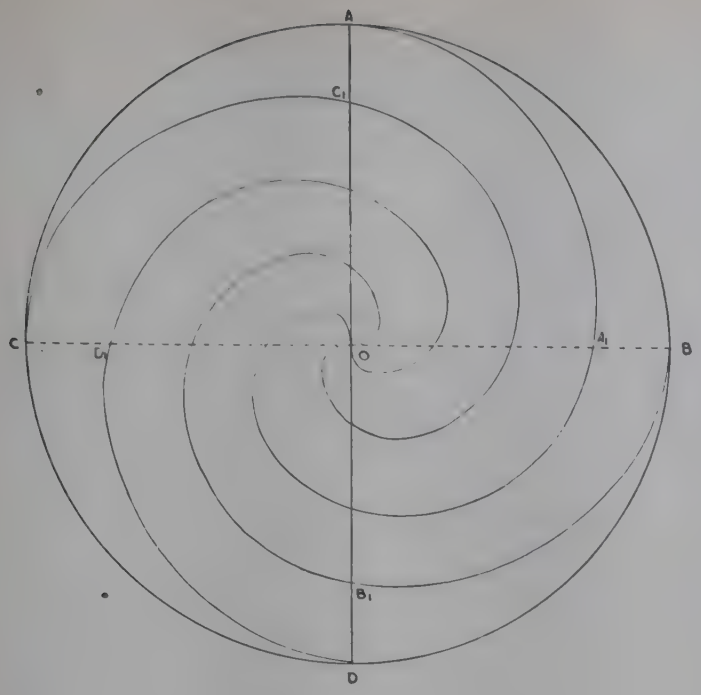



Fig. 1(b)

the evolved surface is equal to the intensity of matter associated with the positions at the equality equilibrium surface. If, from this equality equilibrium state, the tetrahedron would collapse to the central position the associated matter magnitude of the four positions would progressively decrease to least at the centre and the energy distribution at the evolved surfaces would progressively be more concentrated; thereby energy intensity would be simultaneously increased to maximum and simultaneously magnitude of variability associated with the positions would also progressively decrease such that at the centre, the magnitude of matter in association with energy would be least, intensity of energy highest, space configuration would be least and the variability associated with the positions least etc.

We have up till now described only the portion of the spherical wave between the centre and the equality equilibrium spherical surface state. If the magnitude of space would be further increased beyond the equality equilibrium state, the intensity of energy in the created space would further be decreased and the association of matter would further increase in intensity. Beyond the equality equilibrium state, in addition to the increase or decrease in magnitudes of the respective dimensions, a new phenomenon occurs; a change in the orientation of configuration as well as a change in the phase of energy and matter occurs. Upto the equality equilibrium from the centre, between the centre and the equality equilibrium surface, it was only one configuration for both energy and matter and they were in one phase in which the two were associating with each other in the same configuration. But in the evolution of the configuration beyond the equality equilibrium state, energy and matter segregate. Energy belongs to one configuration and the matter belongs to another. But both retain their properties as opposites.

The configuration of the universal spherical wave retains regular tetrahedral evolutionary mechanism from start to finish. This has been depicted in the figures 2(a) and 2(b).

There are two distinct zones in the configuration of the wave. One zone is between the centre and the equality equilibrium locus of positions ABCD and the other zone, which is beyond this central zone, lies between the equality equilibrium ABCD and the boundary of the wave WXYZ. In the central zone, the configuration of tetrahedron is only one with O as the centre. The 4 positions emanate from the centre towards ABCD in radial directions. All the 4 position of matter created in this zone are also associated simultaneously with matter and energy and they remain in association together and undergo change or variation in their magnitudes together. Thus the energy and matter start with magnitudes of their intensity as 9 & 1 respectively and proprogressively change in opposite direction as the configuration increases to ABCD where they assume magnitudes of equality of 5. Up to this state of the configuration of the universal wave, the energy and matter or the fundamental and derived dimensions form one configuration together. Whatever modification occurs in the configuration, their magnitudes change simultaneously also, but in opposite directions between the limits 9: 1 at the centre and 5 : 5 at the equality equilibrium. In the heterogeneous field zone of the configuration of the universal wave between the equality equilibrium ABCD and the boundary WXYZ, the energy and matter form two distinct phases. Each of the 4 segregated tetrahedrons is a configuration of segregated matter positions having distinct configurations of its own. Their statistical occurrence in the boundary of the outer zone gives 4 configurations of tetrahedrons retaining tetrahedral structural symmetry in the outer zone. In the outer zone the field space, outside the 4 tetrahedrons, energy intensity radially varies from equality equilibrium ABCD towards the boundary WXYZ diminishing in energy intensity as 5, 4, 3, 2, 1 whereas in each of the 4 individual tetrahedrons, the triangular faces of which were coinciding with the 4 triangular faces of the central tetrahedron at the equality equilibrium state, progressively decreases in triangular surface area till each of the 4 components of 3 positions progressively converges to a point of

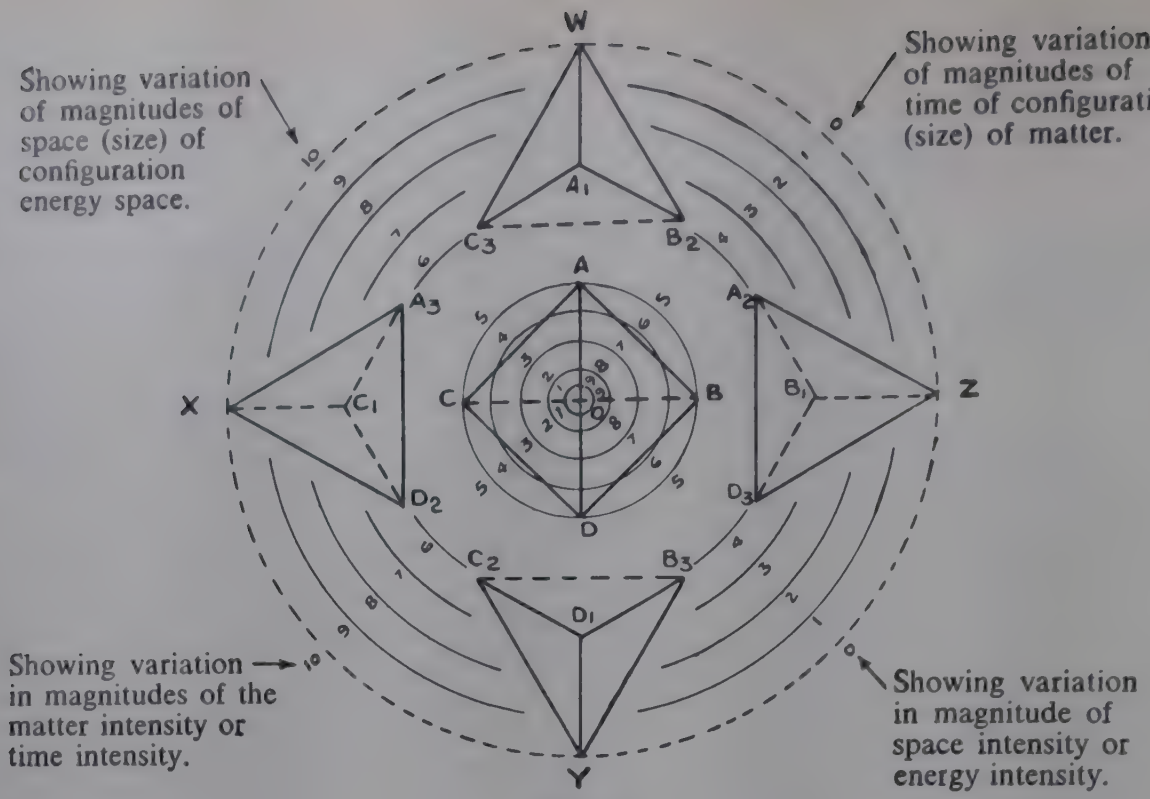



Fig. 2(a)

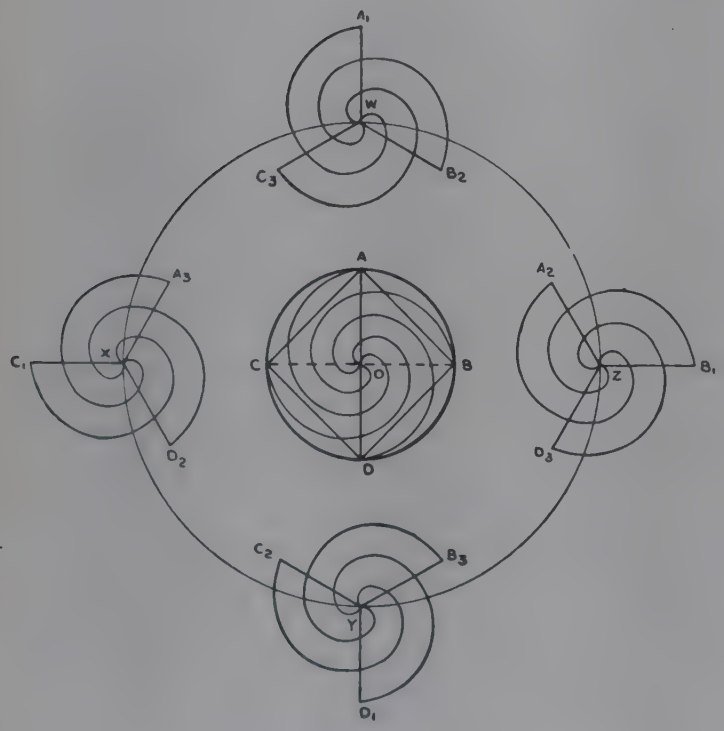


Fig. 2(b)

position at boundary WXYZ. In this process, the matter magnitude at equality equilibrium, which was covered by the triangular face area at that state, was of magnitude of 5 in equilibrium with energy of magnitude 5. Progressively as the triangular face area moves towards boundary, the magnitude of the tetrahedron also progressively diminishes and the magnitude of matter intensity increases. Thus the magnitude of matter intensity from the equality equilibrium increases as 5, 6, 7, 8, 9 the corresponding variation in magnitude of intensity of energy in the field space surrounding the tetrahedrons representing matter configuration is as 5, 4, 3, 2, 1. In the heterogeneous zone, the equilibrium is between matter with field energy which form two distinct and different phases. The magnitudes at equilibrium combination between the two dimensions would be 5 : 5 at the equality equilibrium state and would pass through combinations at different stages through 6 : 4, 7 : 3, 8 : 2, finally at 9 : 1 for matter and energy at boundary. The universal wave begins evolution starting with two in one from centre up to the equality equilibrium. From equality equilibrium, where the two assume one of equality, they vary progressively as two separates so that magnitudes of their intensities change in opposite directions till they are at maximum inequality at the boundary as 9 : 1. With progress of evolution from the equality equilibrium in the configuration of the wave, segregation starts. The derived dimension increases in its intensity in one phase till it reaches the maximum 9 which forms the finite boundary of the wave and in another phase, which represents the intensity of the fundamental, whose magnitude varies in opposite direction till it decreases to least magnitude of 1 which would again be at the locus of the boundary.

This variation of the relative magnitudes of fundamental and derived dimensions viz. energy and matter between the centre and the boundary numerically is shown as follows:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Energy |
| 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | Matter |
| Boundary | | | | Equality equilibrium | | | | Centre | |

At the start of finite evolution from the centre having magnitudes of the energy and matter dimensions as 9 and 1 rèspectively, the created positions of matter assumes the property which is called variability associated with the positions. As the matter intensity of the positions increases, the magnitude of variability associated with the positions also increases. Thus, if the magnitude of matter and magnitude of variability associated with the matter positions would be numerically presented, that would be as follows:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | Matter |
| 1 | 2 | 3 | 4 | 5 | 4 | 3 | 2 | 1 | variability. |
| Boundary | | | | Equality equilibrium | | | | Centre | |

The main points of significance are that up to the equality equilibrium, during evolution, the matter positions associated with increasing magnitudes of variability with increasing magnitudes of matter in one spacial configuration up to the equality equilibrium 5 : 5. This is within the homogeneous zone from the equality equilibrium, matter magnitudes towards the boundary positions namely 'X' increase as 6, 7, 8, 9 whereas the magnitudes of variability of the positions towards 'X' (3 triangular positions corresponding to one component of 3 from 4 central tetrahedral positions) vary as 4 3 2 1. The picture is that the 3 directional matter from the position, say, at 'X', when its configuration would be varying towards the centre up to the equality equalibrium, the 3 directional variation of the positions will increase to maximum at equality equilibrium; in the process, the segregated matter magnitudes was maximum at the boundary and least at the equality equilibrium. On the other hand, from the centre wherefrom the evolution starts with least magnitude of matter associated with positions in four directional space, as the configuration increases, the matter magnitudes associated with the positions also increase in four variable directions. Variability associated with the positions increases progressively till it becomes maximum at the equality equilibrium. Thus the magnitude of variability associated with the positions in the homogeneous and heterogeneous zones, is least at the centre and the boundary and maximum at the equality equilibrium but the variation is four directional within the homogeneous zone and 3 directional in the heterogeneous zone.

The above, in a nutshell, is the mechanism of the configuration of universal wave.

The fundamental law of evolution in the concept of universal wave could be briefly summarised as:

If something would evolve out of nothing and would subsequently establish an equilibrium concept of configuration, there must be a fundamental dimension as Cause creating the evolution. From a state of indefinable fundamental, of finite intensity and purity, having no configuration, the finite evolution starts through a state of point of position of fundamental assuming finite highest magnitude associating with least magnitude of derived opposite dimension assuming 4 directional isotropic probabilities. The fundamental and derived opposites assume regular tetrahedral configuration in association with their containing dimensions. The two, from the state of point of position, undergo variation in their magnitudes in opposite directions in the same tetrahedral configuration till their magnitudes equalise at a state of equality equilibrium from which state the two equals segregate and continue to vary inversely in their magnitudes in two phases till the magnitude of derived becomes highest in one phase and that of fundamental least in the other at a state which forms the boundary of the universal wave.

The variation associated with the positions in the homogeneous zone between the centre and the equality equilibrium increases in magnitude from the least at the centre to highest at the equality equilibrium, assuming 4 directional characteristics. In the heterogeneous zone between the boundary and the equality equilibrium magnitude of variability associated with segregated matter positions start with least variability at the boundary, increases to maximum at the equality equilibrium assuming 3 directional characteristics.

Equilibrium configuration of the wave is established, due to the action and reaction of magnitudes of intensities of the two opposites, viz. fundamental and derived (e.g. energy and matter) and the magnitudes of size of their containing dimensions (viz. space and time) which are opposite to those of the containers. The four dimensions: 2 opposite pairs of 2 opposites make equilibrium concept of regular tetrahedral configuration of universal wave which is symbolically presented as

$$+/- \;=\; -/+$$

This universal law of evolution has been applied in the finite 4 dimensional energy, matter, space and time manifestations of the inanimate universe, dimensional equilibrium concept of which has been represented as E/M=L/T or ET/ML=a constant. Incorporating the postulates of the theory that space L is radial and 4 directional and time T is orbital and 3 directional, the equilibrium dimensional relationship was expressed as $ET/ML=L^4/T^3$ or $ET^4/ML^5$=equilibrium constant. The latter has the same dimensional significance as that of the conventional gravitational constant.

**Equation of equilibrium**

We, whether as animate human beings or inanimate entities like material crystals, are all equilibrium manifestations or phenomena. What all we observe are also objects or forms that exist in equilibrium relative to our relative position of observation. Naturally one should enquire about the significance of the word "Equilibrium". This significance of equilibrium in a finite existence of anything finite must be between two finite opposites. (Infinite existence is another which has been explained before as abstract.) A conventional equation is symbolically expressed as A=B between two as A and B as finites. What does it signify ? It signifies that the magnitudes of two finites, one of A and another of B are equal. But is that enough to express the entire significance of equilibrium? Is A the same as B or different? The enquiry is not merely about the magnitude of the two; but about the nature and property of the two as well; about action and reaction of the two; about the direction of action of the two and about their co-ordinates.

There should be no doubt that A and B must be of equal magnitude to maintain the equality equilibrium. But they must be opposite in their functioning. If A acts, B reacts. Action and reaction can be of equal magnitude but they are opposites. If they are identical and their magnitudes are equal, then presentation of equality equilibrium in that case should be as A=A or B=B and not A=B.

Take, for example, the case of an orange and a lemon. Intrinsically, the two are different. But it may so happen that both the two entities may produce identical smell and flavour at a position in between the two where it may not be possible for the observer to distinguish between the two situated at that position. In this case if the orange is A the lemon could be B and the equation of equality could be written as

$$A=B$$

The symbols of either side of the equality equation must incorporate the coordinates on the dimensions the symbols stand for.

The universal spherical wave as applied to inanimate Universe is an equilibrium configuration between the magnitudes of dimensions ETLM. Energy and matter are dimensions having opposite significance. Similarly space and time have also opposite significance. The direction of space is radial and the direction of time is orbital. Space as containing dimension of energy again is opposite to that of time relative to latter, since higher magnitude of size of space leads to lower intensity of energy. Higher the intensity of energy the lower is the magnitude of size of space containing it. Similarly, matter and time dimensions are opposites. Expressing the equilibrium equation for the universal spherical wave of energy matter evolutionary field, the equilibrium equation would obviously be written as

$$E/L=M/T$$

If the equilibrium is considered at a state of equilibrium of equality then ET/ML=equilibrium constant as unity. If, however, an equilibrium state of existence in the universal spherical wave would be considered at any other state than the equality equilibrium state, the magnitude of equilibrium constant will also be different. Thus the equilibrium constant for the equilibrium equation of the dimensions ETML would be as follows:

$$ET/ML = \frac{\text{Power of space coordinates}}{\text{Power of time coordinates}}$$

Since space is 4 directional and time is 3 directional. Therefore $ET/ML=L^4/T^3$ or $ET^4/ML^5$=constant of equilibrium magnitude of which can vary between 1 and $\pm$ infinity. The dimensional significance of ETML was identified with the dimensional significance of degeneracy parameter in modern statistics (Vide *Technology* **2** (4) 1965, page 226).

**Recapitulation**

In order to have a clear grasp of the concept of universal wave and the gradients of magnitudes of various dimensions constituting the configuration one should particularly acquaint himself with the various detailed considerations and implications of the basic aspects. Unless one gives concentrated thoughts to each one of these aspects in detail, (leaving aside for the moment the established ideas and approaches as per modern scientific thoughts) and applies those in mental picture to seek explanation, in this light, to various phenomena experienced, the total significance of the resultant picture of the universal wave taking

into account all aspects in proper perspective will be difficult to follow. The main aspects, therefore, are briefly mentioned below for recapitulation:

**Main aspects of the universal wave**

1. In the universe, imagination of a concept and objective realisation of the same by perception through physical means cannot be reproduced in full.

2. Maximum realisation of configuration of the universal waves would, therefore, be only finite; however high or low the magnitude at the extreme limits may be, those must be finite and assume finite configuration.

3. For knowing the true mechanism of creation of something evolving out of nothing, it requires a fundamental dimension as Cause.

4. The fundamental dimension in its abstract state, prior to finite creation, possesses infinite magnitude of purity and intensity, having? finite configuration of that state but only an imaginary tetrahedral configuration.

5. Equilibrium in the finite creation is maintained by association in variation of magnitudes of four dimensions including the fundamental in finite form between finite opposite limits.

6. The equilibrium in creation is established by the action and reaction of the magnitudes of fundamental and derived dimensions.

7. In creation, the fundamental dimension is always expansive and the derived dimension is contractive.

8. Equilibrium configuration is generated by the action and reaction of co-ordinates of containing dimensions of the fundamental and derived, viz. space for energy as the fundamental dimension and time for matter, the derived dimension.

9. Space is 4 directional and functionally it is radial. Time is three directional and functionally it is orbital.

10. Creation of evolution occurs through point of position of fundamental assuming perfect isotropic tetrahedral mode which defines the centre, the boundary and the equality equilibrium of the configuration of universal wave.

11. In configuration of creation—four dimensions: two opposite pairs of two opposites vary in their magnitudes in opposite modes between two limits of nil and infinity which define the centre and the boundary of the wave.

12. The equality equilibrium state in the creation between the two opposite limits is a stage at which the magnitudes of the different dimensions assume statistical magnitudes of equality.

13. Potential gradient (of intensity) of fundamental dimension is in decreasing order from centre to boundary; and potential gradient of intensity of derived is in increasing order in the same direction.

14. Two distinct zones in the configuration of the universal wave: homogeneous zone in which two exist in one and heterogenous zone in which two exist as separates.

15. Significance of variability in the configuration of universal wave—maximum at equality equilibrium state and least at boundary as well as centre.

16. In the created manifestation, the fundamental degenerates in purity or intensity and becomes finite in association with other dimensions.

**Law of evolution**

Mechanism of evolution of the universal space field is due to fundamental dimension energy, which starts the creation, by assuming a point of position with its highest intensity associated with least intensity of matter. The point of position is itself a regular tetrahedral configuration of least magnitude, the fundamental dimension taking up the position with highest intensity at the centre with least intensity of derived occupying the 4 position. Up to the equality equilibrium surface ABCD in figure 2a, the tetrahedral configuration, with the fundamental and derived dimensions occupying the respective positions, decreases and increases in their magnitudes respectively with simultaneous association of increasing magnitude of variability of the positions (tetrahedral configuration being retained); the intensity of energy decreases while the intensity of matter positions increases simultaneously till both matter and energy arrive at magnitude of equality in their intensity at the equality equilibrium surface. The whole development up to this state had taken place, energy and matter at the various states of development up to the equality equilibrium occupying only one tetrahedral configuration, but with increasing magnitude of variability associated with the positions. In the energy field of the universe the zone of the spherical wave between the centre and the equality equilibrium has been termed 'homogeneous zone' or 'kinetic zone'. The essential aspect in this zone is that the energy and matter significances associated with the tetrahedral positions are inseparable. The development takes place in one configuration. One cannot be isolated from the other and

they have not been segregated from one another. During this development both energy and matter are in one configuration. Although the magnitude of the tetrahedral configuration expands through various intermediate states between the two limits, the centre and the equality equilibrium, the magnitudes of energy and matter varying in opposite directions. This zone signifies association of two in one but their magnitudes vary in opposite directions while the size of configuration and magnitude of variability vary in one direction.

From this, it would be clear that in this zone the energy and matter significance as one cannot be separated. If one dimension is there, the other, which is its anti or opposite, also remains in combination. If matter is one dimension, its opposite dimension energy which is anti matter is also in combination. Simultaneously if energy is the dimension, its opposite which is matter significance is also associated with it (of course, up to the equality equilibrium surface the matter significance is only as momentum of energy and not segregated as elementary atomic matter). Matter is anti energy and antimatter is energy. In any state, the two occur in combination in the finite universe, one constitutent being matter, and the other constituent which is anti matter or energy being also simultaneously present. Between the centre and the equality equilibrium, the two are as one and when the configuration varies in magnitude, the intensities of the two dimensions in combination vary along various states in opposite direction. If the magnitude of intensity of matter increases from one state to another, the intensity of energy decreases in the same direction.

The symbolic presentation of the evolution in terms of the magnitude of two dimensions from starting state of point of position through the equality equilibrium up to the boundary could be descriptively represented as follows:

Up to the equality equilibrium the evolution takes place assuming one configuration in which the two opposite dimensions vary in opposite direction in their magnitudes in such a way that, as the fundamental dimension creating the evolutionary manifestation decreases in magnitude, the magnitude of the derived dimension progressively increases till both arrive at a state of magnitude of equality. From this state in the evolutionary manifestation, as the evolution progresses further i.e. the configuration of the wave increases the 4 positions of the tetrahedron at the equality equilibrium state vary outward in four directions, developing progressive increase of space field configuration radially outward towards the boundary, resulting in progressive decrease in intensity of energy in space in successive states. The boundary would be a state where the configuration of space would be biggest but that would be completely depleted in energy content, i.e. that would be a state where as far as the universal space in the configuration of the spherical wave is concerned, the intensity of energy in space would be lowest.

In the outer field, which is termed as heterogeneous zone or potential zone, the matter dimension assumes distinct configurations of its own but gets segregated and remains in equilibrium with space field with corresponding field energy intensity: a phenomenon similar to precipitation of crystals from mother liquor, liquor depending on temperature and solubility characteristics. In the universal spherical wave each configuration of matter dimension in the outer field starts with three segregated positions as one triangular face, whose size is the same as one of the triangular face of the central tetrahedron at ABCD at the equality equilibrium state.

As the space magnitude in the outer field increases radially from the equality equilibrium, correspondingly each triangular face of three positions of the tetra-

| Variability | At the boundary | Matter intensity | Energy intensity | |
|---|---|---|---|---|
| Least | | Highest | lowest | |
| Lower | | lower | higher | |
| lower | | lower | higher | Two vary as separates in the heterogeneous zone. |
| | | lower | higher | |
| highest | At the equality equilibrium | Two equals | | |
| lower | | lower | higher | |
| lower | | lower | higher | Two vary as in one in the homogeneous zone. |
| least | Starting point of position as centre | lower | higher | |
| | | lowest | highest | |

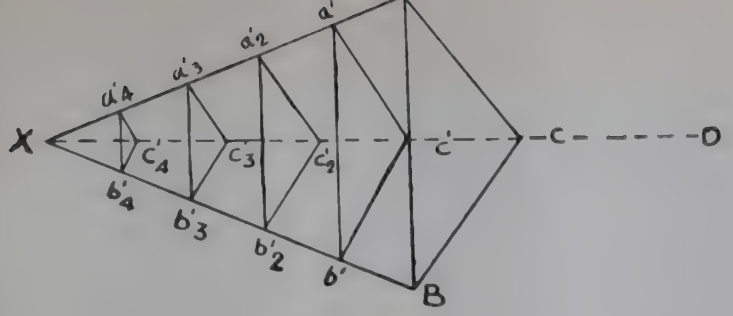



Fig. 3

hedron occupying matter dimension decreases in size as say a′ b′ c′, $a_2'$ $b_2'$ $c_2'$, $a_3'$ $b_3'$ $c_3'$ etc., towards the apex X, while the magnitude of matter intensity progressively increases till the matter intensity becomes highest in magnitude at the apex point of position X at the boundary of the universal spherical wave following isotropic development in 4 directions. At the boundary, thus, there would be found 4 probable positions of derived dimensions matter of highest magnitude in intensity in equilibrium with space field having lowest intensity of the fundamental dimension as field energy. These 4 probable positions at the boundary together also retain their regular tetrahedral configuration. The magnitude of variability associated with the positions, which was maximum at the equality equilibrium surface, progressively decreases towards the boundary as the matter positions pass through the various states of increasing intensity, till, at the boundary at WXYZ, the magnitude of variability of positions becomes least.

In the configuration of the universal spherical wave, there are three important states. The first state is the centre at which the fundamental dimension is in its purest form with highest intensity where it is associated with least intensity of derived in tetrahedral configuration of least magnitude of size and having least associated variability. At the state of equality equilibrium the associated magnitude of variability rises to maximum. Any change between the equality equilibrium and the centre in the two dimensions vary in their magnitudes of intensity in opposite directions but they vary as one in one configuration. From the equality equilibrium towards the boundary, the magnitudes of the two dimensions vary in segregated forms, energy as space field varies with progressive decrease of intensity of energy contained in it towards the boundary and the matter dimension, assuming segregated configuration varies with increasing magnitude of intensity of matter in its configuration towards the boundary with simultaneous decrease in magnitude of associated variability. The boundary state of the finite spherical wave would be one at which the matter positions would have highest intensity associated with least variability in its segregated configuration in equilibrium with surrounding space field whose energy intensity is least.

Now the question is: what would be beyond the boundary and what was before the centre? The configuration of the universal sperical wave thus described is of the finite wave between the centre and the boundary. Before the centre or prior to the centre, i.e. before the configuration was formed, the fundamental dimension as the cause, was in its abstract state of existence about which no configurational description is possible. In that state, the fundamental dimension was not associated with any other: the fundamental dimension was in its infinitely pure state of existence with nil variability associated and having no space/time configuration of its own. This is a state which one can only imagine where the fundamental dimension is of infinite magnitude of intensity and purity and occupies nil magnitude of space field configuration (not merely least). But this does not give any concrete picture of configuration of the fundamental dimension and its concept. One can, however, venture to suggest (as has been explained before) that since the fundamental dimension, when it starts assuming a finite manifestation, starts from the point of position, with its highest occupying the centre of regular tetrahedral configuration of positions containing least of derived and again when evolution ends up at a finite boundary where also its opposite in its highest retains tetrahedral configuration but having least of fundamental in between. The configuration of the fundamental dimension in its abstract state is one in which the 4 positions of the fundamental dimension of infinite magnitude of intensity and purity occupies the imaginary centre of the imaginary tetrahedron. Similarly matter or derived dimension beyond the boundary would be one at which the 4 positions would have the probability of infinite intensity having three imaginary positions of each or three probabilities.

**Concept of configuration fundamental dimension in the abstract state and the doctrine of Maya applied to finite manifestation in ancient times**

It should be noted that in the philosophies in ancient India the description of Shuddha or Parambrahma (शुद्ध या परम्ब्रह्म) as Nirakar Parambrahma (निराकार परमब्रह्म) and other ways of describing it always retain this concept of imaginary tetrahedral ABSOLUTE.

There are two aspects of magnitude of space/time coordinates in the configuration of the universal spherical wave. One is the magnitude of size of configuration (as Pradhan): the other is the magnitude of the intensity of configuration (as Mahatta). The size of the configuration refers to the aspect of the magnitude of the extent of configuration. The intensity of configuration refers to

the intensity of content of the configuration. Naturally, when a configuration is started by one fundamental dimension of certain magnitude which varies in intensity with the magnitude of size of configuration consequently as size increases the magnitude of the content of fundamental decreases in intensity. Thus in space/time configuration of the universal spherical wave, energy creates space configuration; as the magnitude of space increases, energy intensity decreases. The intensity of energy is opposite of the magnitude of size of the configuration of space. If the magnitude of configuration decreases, the intensity of energy increases. Now since energy itself is space and space has no existence without energy and the configuration of the space field itself also determines the intensity of energy associated with it, energy itself can be computed as the intensity of space configuration which should be opposite to the magnitude of size concept of configuration. Similar is the case with the expression of magnitude of matter relative to the magnitude of time in configuration. Matter creates time orbit on configuration in the space field. If the size of the time orbit is big, intensity of matter is less in the orbit. If the orbit is small, the intensity of matter occupying positions in the orbit is also high. Thus the time orbit in terms of matter intensity would be exactly opposite in terms of the size of the orbit. Thus the magnitude of intensity of time orbit can be expressed as matter intensity. As the size of the orbital time configuration increases, the matter intensity decreases. Strictly speaking the so-called matter and energy, as would be realised in the light of the "Theory of Energy Field of the Universe and Atom" as intensities of time and space respectively in the space time configuration of the universal energy/matter space/time spherical wave. The universal spherical wave as such is energy-matter equilibrium in terms of co-ordinates of the dimensions of space and time between their magnitudes of size of configuration and magnitudes of their intensities. This naturally would reduce to the same deduction and conclusion as was in ancient times. "In the ultimate analysis in the universe there is nothing substantial as it appears to our senses and perception.Every thing is bound to reduce to magnitudes of configurational size and intensities of space and time." There could be hardly any objection in the argument and deduction made in the ancient times leading to the doctrine of Maya (माया) or illusion in the ultimate analysis about universal manifestations which must have been deduced in the background of logic of similar deductions as have been done in the present theory.

Strictly speaking, the so-called matter and energy are in reality the intensities of time and intensities of space, in the space-time configuration of the universal spherical wave which naturally can logically lead to the idea that the concept of dimensions of matter and energy, as having some concrete substance in them, is only imaginary. The equilibrium configuration of the universal spherical wave as such is a resultant configuration due to the action and reaction of the magnitudes of space and time co-ordinates between their sizes and their intensities.

**Concept of Fundamental in Ancient Indian Philosophy**

The concept of fundamental dimension in its abstract state prior to finite created manifestation due to the fundamental as the cause is an identical concept underlying in the concept of fundamental dimensions as Param Brahman or Param Atman (परम ब्रह्म या परम आत्मन्). In the Brahmasutras (ब्रह्मसूत्र) starting with Sutra No. 1 to Sutra No. 32 the two aspects of Brahman have been described. These are: One in the infinite state and the other in the finite state of existence. Infinite state is a state of one only. In the finite there are two regions: homogeneous and heterogeneous (Abheda and Bheda) in which the fundamental assumes finite form in association with derived opposite dimension [refer figs 1(a) 1(b)]. In the energy field theory the fundamental dimension in the finite wave manifests in the two regions as two as one in one region and two as separates in the other region. The concept of the fundamental dimension in the abstract state prior to evolution, relates to only one in a surrounding or configuration of nothing. Brahman and Atman in the finite manifestation of the universal wave is just similar to the concept of energy and matter adapting finite universal tetrahedral concept of configuration associating with space and time. Whatever exists within the finite universe in terms of derived dimensions like matter as Indriya and Tanmatra forms (इन्द्रिय और तन्मात्रा) are in different phases in different in medium of fundamental dimension like Atman at its different magnitudes of intensities. Space is all covering or all pervading in the finite energy/matter creation. So also the Atman or Brahman is all pervading with the finite Indriya Tanmatric universe. Nothing existing within the energy matter space time universe either as energy/matter as one or energy and elementary matter as separates cannot exist in any phase or form without the simultaneous association of energy as space. In the finite universal field of Atman or Brahman too, Indriya or Tanmatra cannot exist without the association of Atman or Brahman. In both concepts the state prior to the finite evolution the fundamental dimension remains in the indescribable abstract form. In both the

approaches fundamental dimension at that state is of infinite purity or intensity having no association with any other.

The identity of the significance in the two approaches can be cited by numerous slokas and sutras from all Shastras or Scriptures in ancient India. A few slokas may be mentioned below in respect of the fundamental dimension in its abstract state of existence and the nature of the finite evolved configuration where the finite fundamental associates with derived. When the associated dimensions are eliminated from configuration again the fundamental dimension assumes the abstract state of Paramatman or Purusha. For example take the slokas:

१. असंगो अयम् पुरुषः इति
२. शरीरादि व्यातिरिक्तः पुमान्
३. निर्गुणत्वात्न चिद्धर्मा
४. मूले मूलाभावाद् मूलं मूलम्

All these indicate that the fundamental dimension in its abstract state is unassociated with anything and the dimensions like Paramatman/Parambrahman in abstract state of existence is of finite intensity and purity unadulterated by any association of other dimensions. This obviously is the state of ONE as Ekam Evam Adwitiyam (एकम् एवम् अद्वितीयम्) This is the state when the finite configuration is destroyed or Pralaya (प्रलय) occurs of derived dimension towards fundamental at the centre of the universal wave. Pralaya of fundamental dimension (if that would occur) would be towards highest of derived and would be at the boundary of the universal wave where the derived dimension would tend to assume infinite magnitude and fundamental nil magnitude. Take further the Slokas:

१. सत्वरजस्तमसां साम्यावस्था प्रकृतिः
प्रकृतेर्म्महान महतो अहंकारो अहंकारात्
पंचतन्मात्राण्युभयमिन्द्रियं मनश्च तन्मात्रेभ्यः
स्थूलभूतानि, पुरुषः इति पंचविंशतिर्गनः
२. जड़प्रकाशायोगात् प्रकाशः ३. महादक्षः मद्यम् कार्यम् तन्मनः
४. चरमो अहंकार ५. तत्कार्यत्व मत्तरेशान्
६. आब्रह्मस्तत्वपर्यन्तम् तत्कृते सृष्टीशविवेकात्
७. ऊर्द्धम् सत्वविशाला ८. तमोविशाला मूलतः
९. मध्ये रजोविशाला

These slokas clearly show the identical significance of evolutionary creation assuming different dimensional concepts with those in the present theory in the created *finite field* of the universal wave, distinguishing between the three states: centre, equality equilibrium and boundary as well as the homogeneous phase Abheda (अभेद) and heterogeneous phases of 2 separates Bheda (भेद) in the configuration.

When the associates derived dimension in the finite energy matter universal wave would get completely eliminated from the configuration, the fundamental dimension is released from derived. In terms of Sankhya this is Mukti (मुक्ति). Further Kapila, the author of Sankhya, says:

तदुच्छिन्तिः पुरुषार्थः तदुच्छिन्तिः पुरुषार्थः

When the fundamental is completely released from the finite configuration, it arrives at the abstract and indescribable state. Further, the tetrahedral configuration of the evolution would be signified by Chaturmukha Brahman (चतुर्मुख ब्रह्मन्)

About the configuration of the fundamental dimension in its abstract state, the theory of universal wave defines it as having an imaginary tetrahedral configuration of nil magnitude, imaginary centre of which occupied by the fundamental in its infinite pure state having nil magnitude of variability associated. The fundamental dimension, whether it is assumed as in the present case as energy or in the ancient time as Atman or Brahman is the cause of evolution of the finite universe. Like the fundamental and derived dimension as energy and matter in the universal space field energy is also space making the evolution; matter the derived dimension occupies position in the created space manifestation. The Atman or Brahman like space creates the universal manifestation and their derived dimensions are manifested like position in space as Jivatma or Pran (जीवात्मा या प्राणः) referring to individuals in the Atmik field like positions in the space field.

The universal wave of energy field has two zones: in one zone two exist as two separates like elementary or atomic matter in the energy field in the heterogeneous zone; so also Tanmatrik Indriya (तन्मात्रिक इन्द्रिय) like Jiba or Pran exists in equilibrium with the Atmik field. They exist as separates (Bheda) though it should be noted that both elementary matter atom as well as Jibatma or Pran or Tanmatrik Indriya cannot exist isolated from the fundamental energy space field for former and Atmik field in the latter case respectively. Like the homogeneous zone of the energy field of the universe in which matter and energy remain in one configuration, in the corresponding Atmik universal field also the Atman and Indriya stay together in one configuration as one. This is the Dvaita (द्वैत) state, but it is the state of Abheda (अभेद). In the former case when the two were separated they were Bheda (भेद) two differents. But the fundamental in the abstract state prior to one beyond the

finite manifestation of wave was in a state of infinite purity and a state equivalent to Advaita (अद्वैत). Not only in Vedanta or Brahmasutra, but in any other scriptures also the same concept has been delineated in numerous different manners to convey the same concept. With the configuration of the universal spherical wave of the energy field of the universe and the respective significance of the various dimensions and their variations of their magnitudes in the wave it should be possible to reconcile this unique configuration of universal wave with any different approach towards realisation of the ALMIGHTY and his creation as was described differently in various philosophies namely Tantra, Vedas, Vedanta, Shruti, Bhagavata Purana, Bishnu Purana, Brahmasutra and Brahmavidhya ,Manusamhita and so on and so forth.

For example in the system of Shruti (श्रुति) the fundamental dimension like Brahma (ब्रह्म) is Sat-Chidananda —all knowing, all powerful, all-guide, all-intensive object of Upasana (उपासना), the dispenser of all fruits .....the resort of all that is good as one. The Srutis attribute to this state of the fundamental dimension as Neti, Neti (नेति, नेति) which means endless or infinity. (It is sometimes interpreted in meaning as 'not this—not this' which is not correct. It should be Na+Iti (न+इति) —there is no end). It obviously means state of infiniteness. It is needless to say that this description is the same as the description of the fundamental in the theory of universal wave.

Brahman as infinity is Nirguna (निर्गुण) no property or no configuration and in the finite creation Brahman is Saguna (सगुण) having finite configuration and properties.

Further, as would be found in the Bhagavata Purana "At Pralaya the Sakti of Bhagavan was asleep (calm). That Sakti is Maya, which is Sad-Asat or Existing—non-Existing, existing eternally as root, and not so existing as forms. Following the law of periodicity (Kala), Purusa fecundated Maya. Mahat and other principles appeared by Transformation....." Take for example the mechanism of creation as explained in Lilavatara (लीलावतार) in Bhagavata Purana.

[Reference, page 27, Bhagavata Purana—by P. N. Sinha.]

"Creation is divided into two stages. First the creation of the principles themselves or Tatvas which unite to form globes and individuals. This is called Karana creation. Secondly the creation of individuals and of globes. This is called Karya or resultant creation. Following the law of periodicity, the First Purusa energizes the latent Karman or Jiva record of the previous Kalpa, and prepares the ground for the development of the Karman, by setting Prakriti into active transformation. This is the First life wave which caused the principles to appear by themselves. The First Purusa permeated these principles as pure Atman. But the principles could not unite to make the forms, and to make individuals and globes, Purusa as pure Atman could not guide them further, as the gulf between Purusa and Prakriti was too wide. So Purusa had to limit himself further, by uniting with Mula-Prakriti, as one undivided whole, and so becoming the guiding principle of all individual working in our universe, the pervader of all individuals and globes as Atman-Budhi. The Universe as a whole is represented as an Egg and the Second Purusa or Virat-Purusa is the soul of that Egg. Individuals and globes appear as germs in that Egg, and are all brought into manifestation in time by the Third Purusa i.e. Brahma".

All these are reconciled in the light of the constitution of the universal wave. Detailed discussion is not necessary on this in the present context of scope of identifying these details with the configuration and functions of the universal wave of energy field of universe and atom.

**Fundamental dimension in Rig Veda**

Purusha which is the fundamental dimension in Sankhya Postulates for universal evolution as Prakriti has been also mentioned in the Rig Veda, Book X, Hymn 90, Slokas 1-16. A perusal of the Slokas reveals that the tetrahedral concept of evolution with Purusa as the cause and Prakriti as the effect has been reflected in the significance of these slokas indicating that at the time of Rig Veda the Principles of Sankhya and the principle of Universal Wave was already established. For example Purusa fills up all space of the universe which is 10 fingers wide. The significance of 10 fingers should be good enough to recognize that it refer to the universal wave between its centre and the boundary as described in the theory of Energy Field of the Universe and Atom. The concept of tetrahedral evolution is also revealed in the third Sloka that the creatures is 1/4th of Him i.e. 1 tetrahedral coordinate in one direction out of total of 4 such coordinates in 4 directions within the homogeneous zone. Then in the Fourth Sloka 3/4th Purusa went up with 1/4 of Him. This signifies in one direction in the universal wave, one tetrahedron is surrounded by 3 in the heterogeneous Field. In Sloka 5, Purusa causes Viraj. Viraj in Vedic language is equivalent to that of Virat or Pradhan. That the equilibrium existence of the universal wave is established between

the two opposite phases which is the postulate of the theory of the universal wave and which was also the deduction of the Sankhya theory in its Sloka as "Sanchar and Prati Sanchara" is revealed in 5th Sloka of the Rig Veda Book X, Hymn 90; in which it states that from Purusa Viraj is born and again from Viraja Purusa is born and they spread East word and West word. This obviously refer to the finite creation as Prakriti, of which no doubt Purusa is the cause, but the finite wave (just like in the universal wave) exist in equilibrium between the centre and the finite boundary, which are the two opposite states of which at the centre the fundamental (i.e. Purusa) dominates and which reduces to least at the boundary when the derived dimension i.e. Prakriti dominates. The configuration of the universal wave is as equilibrium configuration oscillating between the two extreme states. Further, in Slokas 13 and 14, the creation of the four phases which is the deduction from the Sankhya postulates as Kshiti, Op, Marut, Tej like Earth, Bayu, Sky, Agni. The latter signify those material phases which constitute the Prakriti evolution or material universe. The Sloka 15 again gives the indication of configuration of universal wave in one direction which is associated with 7 fencing sticks and 3 times 7 layers of fuel.

It is now recognised that there is some difficulty in identifying the exact meanings of the words used in the Vedic Slokas with the real significance of Sankhya postulates. The main reason is the usage of terminology peculiar in the Vedic literature which is different from the simple Sanskrit words which were used in other literatures like Gathas, written both prior and after writing of Vedas. The significances of the phrases like Kshiti, Op, Marut, Tej, Bom are parallel in significance to the words like earth, water, Bayu, Agni and Akash or generally as solid, liquid, gas, Energy as Space and nothing. There were two distinct types of languages; though both in Sanskritic in origin but one is simple Sanskrit and the other is a distorted one particularly meant for Vedic Brahmin priest class. This has been discussed in detail in the work "Language and Scripts of Ancient India" by H. K. Bhattacharyya, Oxford Book and Stationery Co., Calcutta.

In the same hymn (No. 90 of book X of Rig Veda) also are mentioned about the evolution of 4 castes like evolution of 4 material phases. In Slokas 11 and 12 the classification of castes amongst human beings depend on the quality or merit, which also results from the same Sankhya postulates have been mentioned. Brahman is the mouth of Purusa, Rajanya or Khatria is the arms of Purusa and thighs and feet as Baishya and Sudra. This is being further discussed in the following section on Significance of Caste System, which form the basic theme of "Manu Samhita".

**Ideology behind caste system in ancient India (Manu-Samhita).**

In the olden days Dharma used to mean rule or law. For example, when things are arranged as per gradient of potentials or merit, each occupy respective positions in the gradient depending on their own merit or potential. Things getting arranged in a direction in order of merit or potential and laws governing their establishment of gradient in the universal wave is known as Dharma. The significance of caste system in terms of Barna order of merit or potential was also evolved and developed in this background. The duties, responsibilities, functions etc. of each Barna were settled according to potential gradient from Brahmana through Kshatriya, Vaishya towards Sudra. The evolution of caste system took its root in the light of the same considerations of the principles of universal wave as was known in those days in the postulates of Sankhya. This would be obvious from the description in Prathama Adhyaya (first chapter) in Manu Samhita (मनु संहिता) from slokas 1-30 in which the significance and application of the Sankhya postulates are first delineated. The generation of caste system was further developed on the basis of same principles from sutra 31 onwards. It would be seen in Manu Samhita in these discourses that the four castes refer to four major potential levels of the universal wave and all attributes to each caste belonging to the various levels also follows from the postulates of the universal wave. The classification of the human beings into four castes which formed the basis of society and civilisation which stood the test of time for thousands of years are now-a-days dubbed as unrealistic and is considered as means for unfair exploitation of one caste by another. This is not correct interpretation. This has arisen because the very basic principles on which the caste system had been based are forgotten these days and no longer those are followed neither in theory nor in practice.

For example, a Brahman was supposed to possess least material possession and must have highest knowledge and conciousness. They must devote wholly and solely in search for truth and wisdom. They must not have any craving for worldly material pleasures and comforts. The attainment of highest degree of Brahmanatta depended on highest magnitude of material sacrifice and least attention for material needs and most towards cultivation of potential of knowledge and conciousness. This property and characteristics of the

dimension Brahmana is unexceptable and none can say that these are unjust or unfair and without meaning. Unfortunately, this approach which was practised in the ancient days has lost its real significance and they are not appreciated these days. The caste system no longer retains those ideological backgrounds and associated properties and functions relative to the various castes in the classification and those are not at all observed. That is the reason why caste system, as is found today, is not acceptable.

**Applications of the postulates of Universal Wave to various disciplines in Ancient India**

It has been claimed elsewhere in the works on this new theory that the law of the universal spherical wave should be of universal applicability in understanding and explaining any phenomenon or event within this finite universe. In the works "Energy Field of the Universe and Atom", Parts I & II, applications of this concept have been made to explain various observed scientific phenomena; it has been shown that almost all the laws in modern science are amenable to explanation in the light of this theory and it has been possible to consistently point out the limitations and inadequacies in the some called modern scientific approaches, etc., etc. In the work on "Energy Field of the Universe and Atom" Part III, the basic postulates of this theory were identified with the original Sankhya postulates in ancient India. It has shown that the Sankhya postulates were employed in ancient times to various scientific facts as well as to the animate domain involving Atman (आत्मन्) Purusha (पुरुष) Prakriti (प्रकृति) Mahat (महत्) and Indriya Tanmatra (इन्द्रिय तन्मात्र) etc. It has shown that the essence of the postulates of the present postulates of the present theory of universal wave were known in the remote past in India. But these were employed to situations and events that prevailed then and which were revelant in those remote days using appropriate dimensions comprehensible and relevant in those days and which were amenable to human intelligence for analysis of various phenomena experienced. These were employed extensively in the mechanism of evolution of sound and the development of muscial sounds and octate tunes. This law formed the basis of evolution of numbers, decimal octate system, astronomy, trigonometry and system of Ayurveda. The main principle in the establishment of equilibrium is due to "action and reaction between two opposite pairs of two opposites".

Significance of equilibrium between two pairs of opposite properties of two opposite dimensions can be extrapolated for application to analyse any state of existence or situation; but the significance of association of opposite properties to each of the two opposite dimensions in the established equilibrium concept must remain operative. For example, cause and effect are two opposites. For establishment of equilibrium between two opposite dimensions each of the two must have association of cause and effect. Instead of taking the properties of the dimensions as cause and effect one can assume the association of the two with their opposite properties as Mahat as intensity and Pradhan as size.

In ancient India this tetrahedral evolutionary equilibrium concept as signified by the term Chaturvyuha (चतुर्व्यूह) was applied in the analysis of all isolated situations or phenomenon or it may be a specific aspect of life. For example equilibrium between two opposite dimensions as Atman and Indriya is established between their Mahat (intensities) and Pradhanatva (size), just as in matter and energy equilibrium is established between their intensities and sizes. As an illustration the application of this principle of tetrahedral evolutionary equilibrium of universal wave as was applied to the Ayurvedic system of medicine would be evident from the following quotation from the introduction to Sankhyya Pravachana Bhashyam in the work:

"Sankhyya Darshanam—(by Mahamahopadhyay Durgacharan Sankhyya-Vedantatirtha, 6th edition: Central Book Agency, Calcutta)—on page 238"

अस्य च सांख्यसंज्ञा सान्वया "संख्यां प्रकुर्वत। चैव प्रकृतिं च प्रचक्षते तत्वानि च चतुर्विशत तेन सांख्याः प्रकीर्तितः" ॥ इत्यादिस्यो भारता दिवावयेमः। संख्या सम्यग्विवेकेनात्मकथनप्रित्यर्थः। अतः सांख्य शब्दस्य योग रूढ़तया "ततकारणं सांख्य योगाधिगम्यम्" इत्यादि श्रुतिषु "एषा तेऽभिहिता सांख्ये बुद्धियोगे त्विमां श्रृणु।" इत्यादिश्रुतिषु च सांख्यशब्देन सांख्य शास्त्रमेव ग्राह्यम्, न पुनरर्थः। न पुनरर्थतरं कल्पनीयमिति।

तदिदं प्रोक्षशास्त्रं चिकित्साशास्त्रवच्चतुर्व्यूहम्। यथा हि रोग आरोग्यं रोगनिदानं भैषज्यमिति चत्वारो व्यूहाः समूहात् चिकित्साशास्त्रस्य प्रतिपाद्यस्तथैव हेयं हानं हेयहेतुर्हानोपायस्चेति चत्वारो व्यूहा मोक्षाशास्त्रस्य प्रतिपाद्या भवन्ति मूभूक्षूर्मिजिज्ञाहितत्वात्। तत्र त्रिविधं दुःखां हेयम्। तदत्यन्तनिवृन्तिर्हानम्। प्रकृतिपुरुषसंयोगद्वाराच विवेको हेयहेतुः। विवेकख्यातिस्तु हनोपाय इति। व्यूहशब्देन चेषाभूपकरण संग्रहः। तत्रचादौफलत्वेनाम्यर्हितं हानं तत्प्रतियोग विद्याचैव च हे प्रतिपादिचिश्यन् शास्त्रकारणः शिष्यावधानाय शास्त्रारंभं प्रतिजानिते।

From what we can see today is that, as if, the most important application of the theory was made in the

domain of various philosphical approaches. The various postulates of the universal wave, particularly the ones which incorporate that 4 dimensions are required for creation and the one amongst them, the fundamental which from its abstract state causes the configuration of finite manifestation, equilibrium of which is generated by the action and reaction of opposites between their coordinates of containing dimensions will be found in almost all scriptures on philosophy namely, the Tantras, Samhitas, Puranas, Shruti, Smriti, Vedanta, Brahmasutra and Brahmabidya etc. etc. The configuration of the fundamental dimension of infinite purity and intensity having no configuration, no variability associated, is the state of Ekam Evam Adyitiyam (एकं एवम् अद्वितीयम्) has been the starting point in all the philosophies dealing with the aspect of cause of creation of evolution. That the dimension fundamental is expansive and derived is contractive was realised in these properties in those days also. Prakash or Samprasaran (समप्रसारण) as expansive property of the fundamental Brahman or Atman (ब्रह्म या आत्मन्) etc. and the contracting property of the derived Indriya was known as Sankochan towards a position. The fundamental dimension and the derived dimension in terms of space time coordinates have their intensities and magnitude of sizes. Thus Atman or Brahman, their magnitudes of intensity of purity was determined by Mahatta (meaning greatness or nobleness) and the size of the space time coordinates was started as Pradhan (प्रधान) or Pradhanatva (प्रधानत्व) connoting the significance of magnitude of size. Like the significance of the fundamental and derived dimensions, the two dimensions Mahat and Pradhan are opposites in significance. Creation is actually due to action and reaction of these opposites. In many philosophical literature there remain today a lot of controversy over these two words, Mahat and Pradhan, particularly in the discourses in commentaries on Sankhya and Vedant controversy between the two have cropped up. Sometimes Pradhan has been made to take the place of the fundamental dimension which is not correct. The confusion generally has arisen because the original real nature of the universal wave, its configuration and functions of various dimensions in the configuration as such have not been retained in the background consideration. Those concepts with time have been mixed up resulting in the confusion in later times. The correct significance of those dimensions like the dimensions in the present theory, for example, EM LT would correspond to Atman, Indriya, Mahat and Pradhan for EMT and L respectively.

In Part III, "Energy Field of the Universe and Atom", it was mentioned that the various Chakras (चक्र) Kundalis (कुण्डली) etc. Graha, Nakshatras, Rashi in astronomy have all had their basis in the universal wave of tetrahedral evolution. In the Tantra (तन्त्र) there are various Yantras (यन्त्र) and Chakras which are nothing but expression of the configuration of the universal wave on a plane of paper in different perspectives. Since the universal wave of tetrahedral structure is 4 directional in space it is extremely difficult to depict the same on a plane of paper in various projections indicating various aspects giving out details of each and every aspect of the configuration. The magnitude of difficulty which was faced in ancient times to express the ideas in terms of configuration can be realised. Careful analysis of the various Yantras and Chakras, particularly in Tantra philosophy would reveal that the conguration is actually the equilibrium configuration of the universal spherical wave. Only difference lies in mode of presentation of equilibrium configuration. In these Yantras and Chakras various triangular faces of the tetrahedral configuration are shown as projection by transformation to a plane and the equilibrium configurations are generated from opposite component configurations generating it.

**Yantras in Tantra Philosophy Identified with Tetrahedral Universal Wave**

In the Tantra philosophy and in the Tantric system of worship, the most important procedure is to follow the configuration of various Yantras (यन्त्र). These Jantras are nothing but the geometrical presentations of various manifestations of attitudes and ideals in finite mental universe following the tetrahedral evolutionary concept as would be revealed in the following analysis.

The basic approach in the Tantra (तन्त्र) is more or less and same as the approaches as mentioned before in the other branches of philosophy. But the Tantric (तान्त्रिक) system is more objective as it gives objective configuration which identifies the basic principles of the universal wave with the basic principles of the Tantric systems of philosophy in ancient India which again were based on the postulates of the Sankhya concept. The unified law in ancient India was the Sankhya postulates which were employed in various systems of philosophy and various methods of worship for self-cultivation adopted therein. Different philosophies covered different branches and different aspects of human philosophy assuming relevant dimensions and configurations there for to improve one's self.

The most crucial aspect in respect of identification of the configuration of the theory of the universal spherical wave is in the tetrahedral symmetry of the various con-

figurations adopted in the Tantric (तान्त्रिक) philosophy called as Yantras (यन्त्र). Jantra means house or configuration. In the Tantric system there are several Jantras which are employed in worship in this system each having different dimensional significance of approach according to capability and suitability depending on individual characteristics. These are all geometrical configurationsin a plane. Some of these are Sree Yantra [Fig.19(a), 19(b)], Yantra Raj (Fig. 16) (यन्त्रराज), Sarvotahotra (Fig. 18) (सर्वोत्तहोत्र), Samhara (Fig. 12) (संहार), Mukti Yantra (Fig. 14) Kali Yantra (Fig. 17) (कालीयन्त्र), Sapta Sato Maha Yantra (Fig. 7) (सप्तसती महायन्त्र). The uniqueness of these Yantras lies in the starting state as equilateral triangle and the equilibrium configurations in all cases are developed by addition of the pairs of these triangles in opposite phases. The basic approach in the construction of these configurations are the arrangement of two equilateral triangles in opposite phases as one which is called Shat Kone (षट्कोण) or Shatchakra as shown in the following:

Fig. 4

A little insight would reveal the secrets of all these Jantras and their identity with the tetrahedral significance of the universal wave of the "Energy Field of the Universe and Atom". A regular tetrahedron, when it is placed on a plane surface on one triangular face, the other 3 triangular faces, when projected on plane surface also result in equilateral triangle whose area however is 4 times the area of one triangular face of the tetrahedron. Thus, a regular tetrahedron on a plane paper can be represented by an equilateral triangle as in the following:

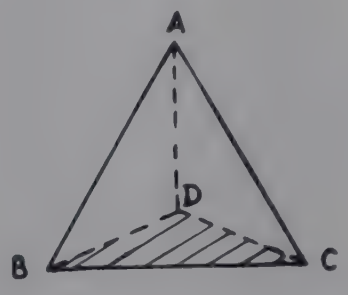



Fig. 5a—Tetrahedron.

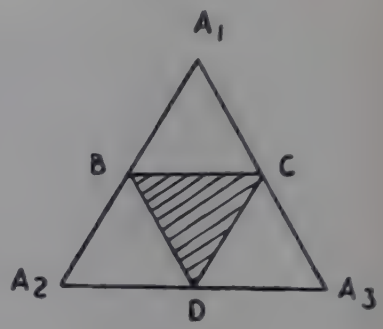



Fig. 5(b)
4 triangular faces in one plane result in equilateral triangle $A_1A_2A_3$. The original position A has to be split or transformed into 3 positions $A_1$, $A_2$ & $A_3$.

The configurations can be either a cube or a octahedron depending on the mode of variation of the positions is opposite phases. With models it would take no time to see the identity of the configurations. These aspects have been discussed in detail in *Technol.*, 4(1), 1967. The significance of the symbol of Shat kone lies in that the configuration of the universe is an equilibrium one formed due to oscillation of two

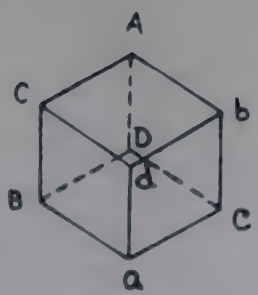



Fig. 6(a)

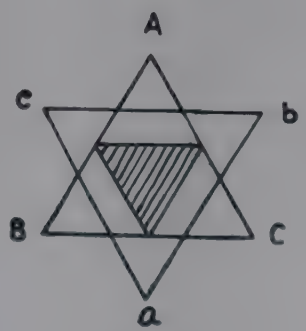



Fig. 6(b)

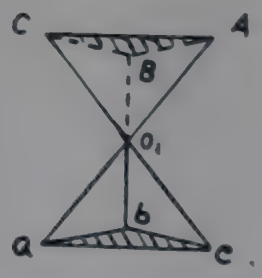



Fig. 6(c)

between opposite phases retaining tetrahedral configuration.

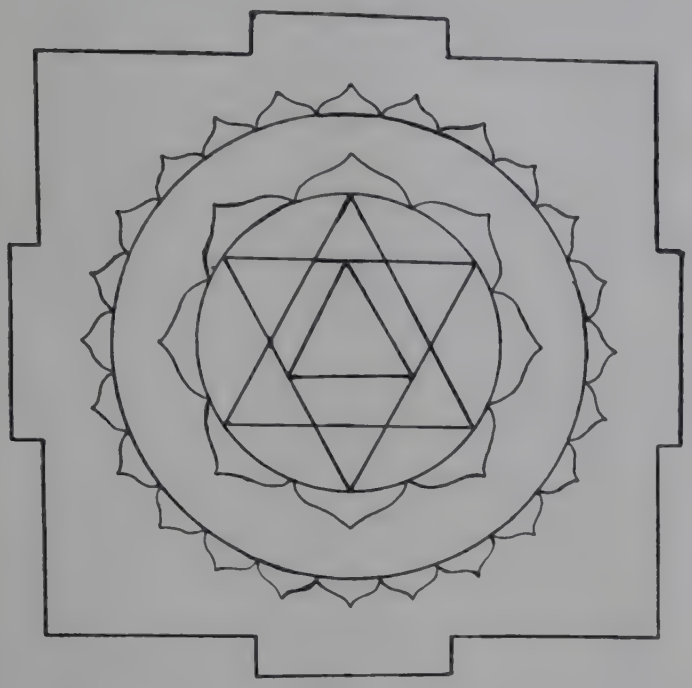


Fig. 7

Sapta Sato Maha Jantra in Shatha Chandi Bidhi is nothing but two regular tetrahedrons vibrating between opposite phases, generating the equilibrium configuration of the Jantra which assumes equilibrium configuration of octahedral or cubical structure.

The configuration of the universal spherical wave can be expressed in relatively simple or complicated configurations. For example, the simple configuration is one in which a central regular tetrahedron is in opposition to four regular tetrahedrons face to face as follows:

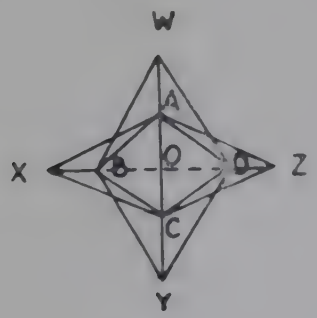



Fig. 8

The four outer tetrahedrons however may each associate with one or two or maximum of three more tetrahedrons each to their three unengaged triangular faces as shown in the following configurations, in which the main evolutionary significance between centre and the boundary and the central homogeneous zone and the outer heterogeneous zone all retain their significance.

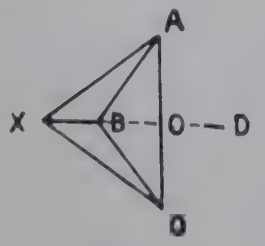



Fig. 9(a)
One outer tetrahedron X is attached to one face of central tetrahedron ABCD.

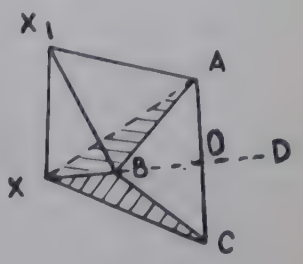



Fig. 9(b)
One tetrahedron $X_1$ is attached to one face of outer tetrahedron X.

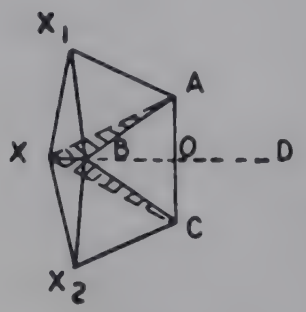



Fig. 9(c)
Two tetrahedrons $X_1$ and $X_3$ are attached to two faces of outer tetrahedron X

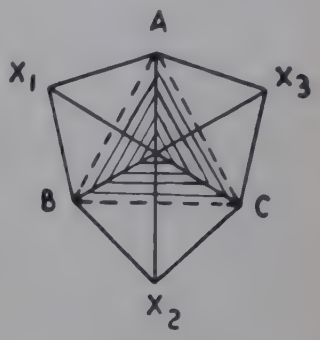



Fig. 9(d)
The tetrahedrons $X_1$, $X_2$ and $X_3$ are attached to three faces of the outer tetrahedron X (Projected on plane when looked in one direction through X to O).

In these configurations of increasing complexity the dimensions composing the equilibrium would have more detailed number of components or phases etc. as would be indicated by the increasing number of tetrahedrons associated with each triangular face of tetrahedron in the outer zone. For example, in the more simple figure where in the configuration there are only four individual tetrahedrons, each tetrahedron took the configuration of derived dimension like matter as one and the surrounding space indicate associated field energy. If there are 3 tetrahedrons associated with each of the outer tetrahedron as in figure 9d that would mean that the matter would have four phases. These four phases would be equivalent to Kshiti, Op, Tej, Marut and the phase of Bom would then be the zone towards the centre. The configuration of the universal wave can be expressed in a simple tetrahedral structural configuration or in more complicated assembly of tetrahedrons in a complicated configuration retaining the overall tetrahedral symmetry as well as the spherical locus symmetry of the boundary and the equality equilibrium state vis-a-vis the centre.

In order to study and analyse the various Yantras and

Chakras in Tantra and also other ancient scriptures, understanding of the mode of presentation of the configurations is of outmost importance. As has been shown in the above, a regular tetrahedron can be represented in terms of the four triangular faces as an equilateral triangle. The configurations of cube and octahedron can represented by two equilateral triangles in opposite phases as Satchakra (सत्चक्र). The nature and complexity of the configurations require to be examined in relation to tetrahedral evolutionary context as to whether the configuration is in relation to one or two or 3 or 4 directions etc. as have been explained before. Further, a configuration can be presented in many ways: by simple outline diagrams linking the positions or interlinking the positions without indicating the outline of boundary or linking the positions between the states of positions between different phases and so on and so forth. To cite an example an octahedron BDC bdc can be represented diagramatically as in following figures:

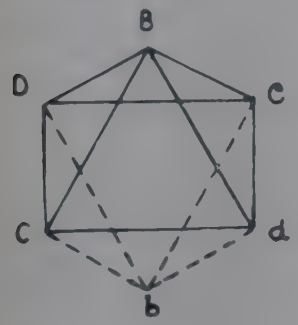



Fig. 10(a)

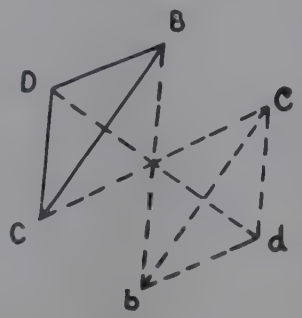



Fig. 10(b)

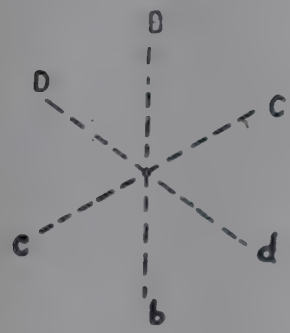



Fig. 10(c)

Fig. 10(d)

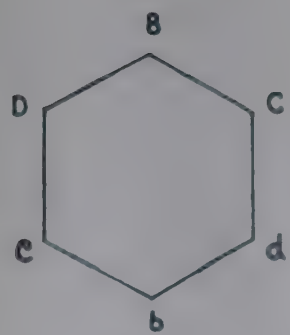



Fig. 10(e)

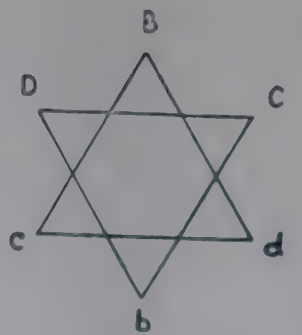



Fig. 10(f)

Similarly, a cube can be represented by the following different configurations:

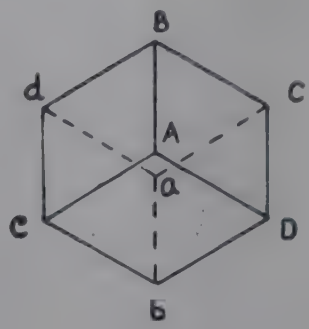



Fig. 11(a)

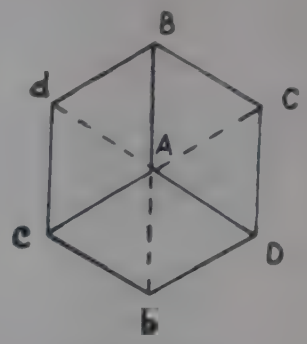



Fig. 11(b)

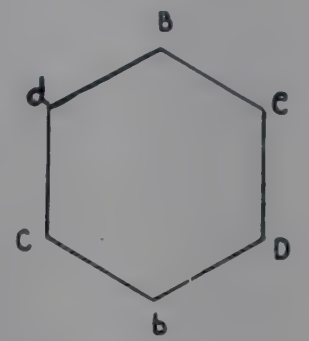



Fig. 11(c)

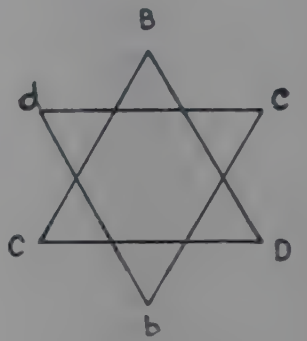



Fig. 11(d)

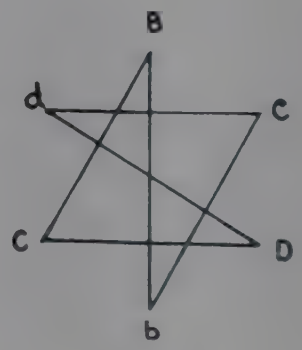



Fig. 11(e)

For example, there is one Yantra called Smarahara Yantra (स्मरहर यन्त्र) whose configuration is normally presented as follows:

Fig. 12

This is a Yantra consisting of 5 positions which actually is the configuration of two regular tetrahedrons in opposite phases placed face to face along one common triangular face. ABCD is one tetrahedron and aBCD is another tetrahedron as shown below:

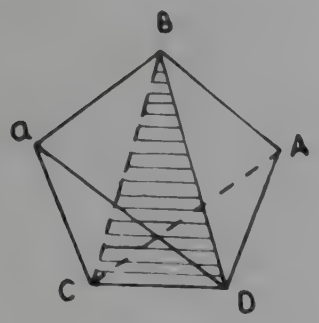



Fig. 13(a)

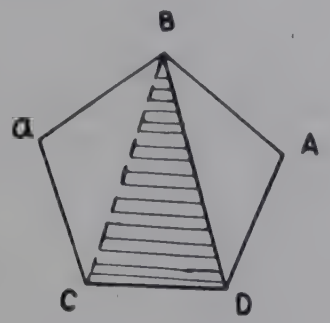



Fig. 13(b)

Fig. 13(c)

If this configuration of two tetrahedrons placed face to face along one triangular face could be presented at plane of paper in several ways: it can be done by showing only the outline of the configuration as in Fig. 13 (b) or by interlinking the positions without showing the outlines as in Fig. 13(c).

The most significant point is that Smarahara Yantra is the configuration of two tetrahedrons placed in opposite phases with one common triangular face.

Another Yantra which is called Mukti Yantra (मुक्ति यन्त्र) in Kumarikalpa (कुमारिकल्प) is normally presented as in the following:

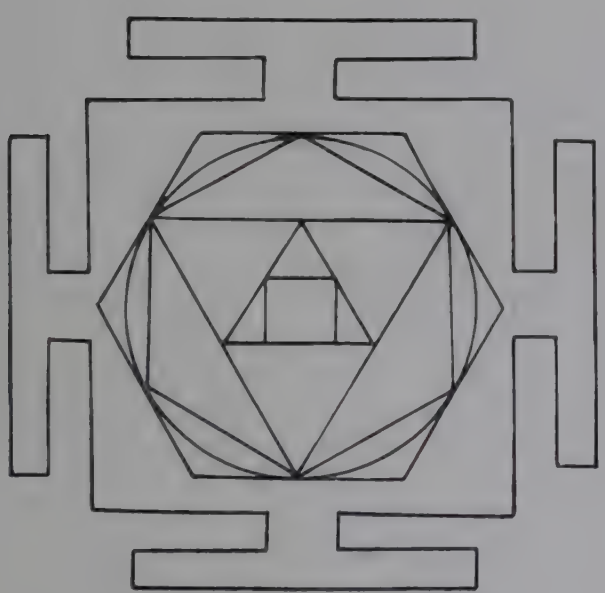


Fig. 14

The rectangle within the central equilateral triangle is resolvable into two equilateral triangles each of whose sides is equal to one joining the mid-points of the sides of the central equilateral triangle and the same Mukti-Yantra with inner rectangle would be in terms of equilateral triangles can be presented in the form as shown in the following retaining tetrahedral significance:

Fig. 15(a)

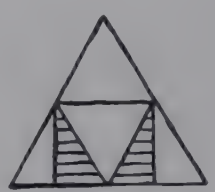


Fig. 15(b)

Fig. 15(c)

Mukti Yantra can thus be presented as in Fig. 15 (d):

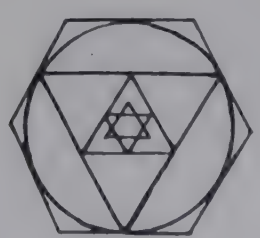


Fig. 15(d)

In ancient India, the Tantras and other philosophies there are numerous Yantras and Kundalis, a few of

which have already been mentioned. Some are simple like only the tri kone surrounded by 16 petals as in the configuration of Yantra Raj in Maha Nirvan Tantra.

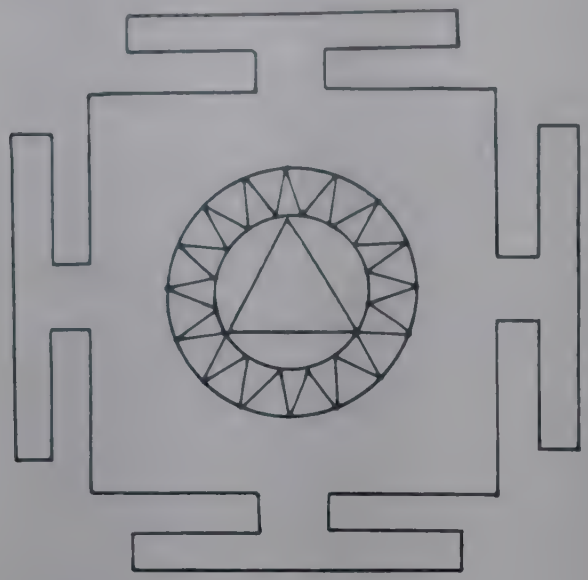


Fig. 16

The significance is obvious. The central tetrahedron is represented by the equilateral triangle and the 16 petals indicated by the 16 corners of the 16 tetrahedrons as found in the outer zone of universal wave.

Take another configuration in Kali Tantra in which a central tetrahedron is in opposition by other tetrahedrons with its progressive association of tetrahedrons face to face starting with one at the centre.

In one direction of the universal spherical wave, all the 8 Kones outside indicate their equilibrium in opposite phases giving a cubical configuration indicative of equality equilibrium state (equilibrium established between the two equal tetrahedrons between opposite phases). This cubical configuration is indicated by also 8 right angles Kones at the periphery. Similarity of the Kali Jantra and Mukti Jantra as converted in Fig. 15d may be noted.

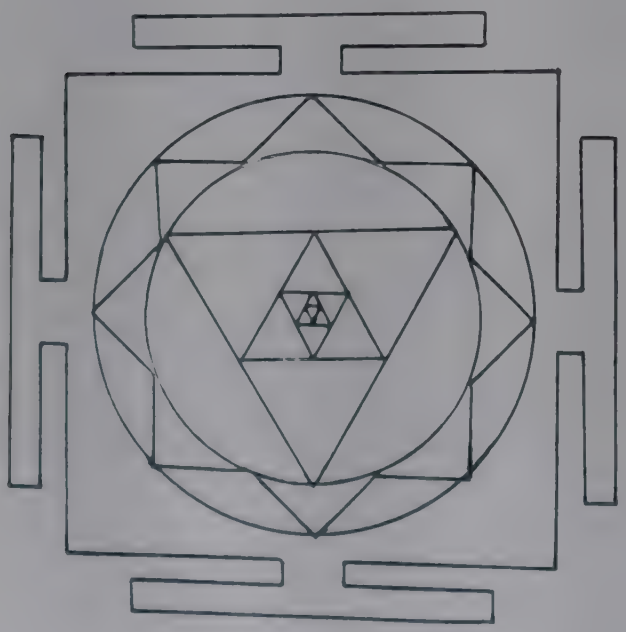


Fig. 17

Another configuration on which is called Sarvota Bhadra Yantra as in Goutamiya Tantra, only indicates 64 squares:

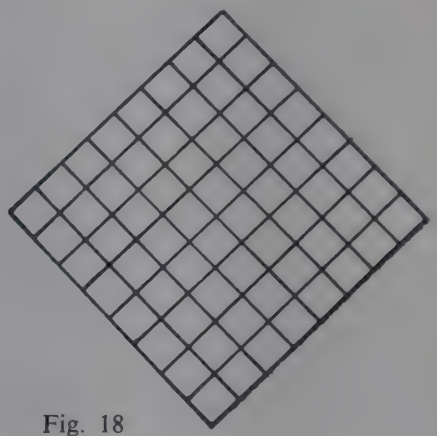


Fig. 18

The significance is not difficult to realise. There are 16 outer tetrahedrons in the heterogeneous zone of the Universal wave of 16 outermost positions. The tetrahedron itself consists of 4 unit squares. This particular configuration of 64 squares units would be appreciated by representing the configuration of universal wave on a plane square graph paper which has been explained later on page 56. The other Yantras with triangular significance would be better appreciated by presenting those on equilateral triangular graph paper.

One of the most important aspects of equilibrium as would be noticed in the foregoing Yantras in Tantra system is that all these Yantras are resultant equilibrium configurations established between opposite phases. That the universe, as it is perceived, is an equilibrium existence of configuration between two extreme opposites was the direct deduction obtained in the ancient times from the Sankhyya postulates.

The configuration of the universal wave in the present theory is also an equilibrium configuration which is generated between a centre and the boundry giving the configuration of the universal wave. If the configuration of universal wave at a particular state would be sought to be brought out say at that of the equality equilibrium state, the configuration would be found to be that of a cube, generated by the oscillation of evolved tetrahedrons

of equal magnitude, each having 4 positions oscillating between opposite phases with highest finite frequency. If the configuration of the universal wave would be considered to be oscillating between start at centre and to finish at boundary and oscillating between these two states then no doubt that the equality equilibrium state is also one state in between the two extreme opposite limits.

All the above Yantras clearly demonstrate the knowledge which was developed in ancient times about the equilibrium configuration of the universe resulting from oscillating between opposite phases. This would be further appreciated from the analysis in details of the configuration of Sree Yantra.

It is said that the most important of the Yantras in Tantra is Sree Yantra. There are two sets of opposite pairs of tetrahedral configuration in Sree Yantra. This significance can be identified with the main deductions of equilibrium existence or equilibrium equation which is deduced in the present theory of universal wave enunciated as:—'Equation of equilibrium is established between the magnitudes of two opposites pairs of two opposites which is symbolically represented as

$$+/- = -/+$$

The Sree Yantra in two opposite pairs expresses the equilibrium existence of the universal configuration as shown in figures 20(a) and 20(b). In one set the configuration relates to the process of evolution of creation characterised by the word—'Srishti Krama' (सृष्टि क्रम). In the second configuration of Sree Yantra the pair of opposites indicates the destruction or Pralaya/Sanhar Krama (प्रलय/संहार क्रम). Needless to say that the mechanism in this case and in the case of configuration of equilibrium of universal wave is identical.

A point however need be mentioned here in respect of the conventional configuration of Sree Yantra. The configuration of the Yantra as found in the various literature is distorted from the actual configuration of Sree Yantra. The main reason for this is that these configurations are the equilibrium configuration of universe drawn on a plane of paper in three directional triangular set up. The distortion in course of time has happened due to two reasons. Firstly, the basic postulates of Sankhya have been confused and secondly, the difficulty in transforming complicated configuration of universal wave on a plane of paper without triangular graphical background. If this modification would be applied to Sree Yantra in the correct background then the configuration of Sree Yantra would be revealed as in figure 19a and 19b. However, even in the conventional Sree Yantra configuration the dominant essentials are retained and there should not be much difficulty in understanding the significance of these configurations. However, in the following attempt has been made to explain the relevant significances from the conventional configuration.

The diagram of the Sri Yantra would show that starting with one central equilateral triangle with the centre (bindu), it is surrounded by 4 pairs of triangles in opposite phases and there are two such opposite sets as shown in Fig. 20(a) and 20(b). The central triangles are in opposite phases in the two Figs. indicating that equilibrium universal evolution is resultant of the vibration of the two configurations in opposite phases, which is also the main theme of equilibrium configuration of the universal wave.

Take Fig. 19, the innermost triangle has 3 kones, the next higher configuration of Kones are 8 in number. The Kones formed by the next higher number of Kones is 10, further there is another 10 and the highest is 14. This is surrounded by 8 petals and outermost petals number 16. In the first configuration Fig. 19 from the bottommost Kone there are 4 Kones till the centre Bindu is arrived. Vertically, above the central Bindu, there are 5 kones in opposite phases to the 4 previous ones, the direction of latter is due to fundamental (as Shiva or Purusha) and the former due to generated by Sakti. The second configuration is just opposite of this. This is very significant in the light of the configuration of the universal wave. The 16 outer petals i.e. the equilibrium configuration of the universal wave oscillate between opposite phases indicating position at the boundary. The next circle of petals numbering 8 is also similar but would indicate positions at equality equilibrium. The most important thing now is to indentify all these Yantras with the 3 directional (3 dimensional) configurations of the tetrahedral structural configuration of the universal wave as has been propounded in the theory of "Universal Wave of the Energy Field of the Universe and Atom". The various dimensional significances which are associated with these Yantras in the various orbital Kones or petals progressively starting from the boundary towards the centre follow similar logic of sequence of dimensional significance as well as variation of magnitudes of the various equilibrium dimensions as has been delineated in the theory of the universal wave. No wonder that these Yantras in ancient India were treated as the progressive development of the evolutionary creation (Sristhi Krama and Sanhar Krama).

The above analysis reveals the real significance of the

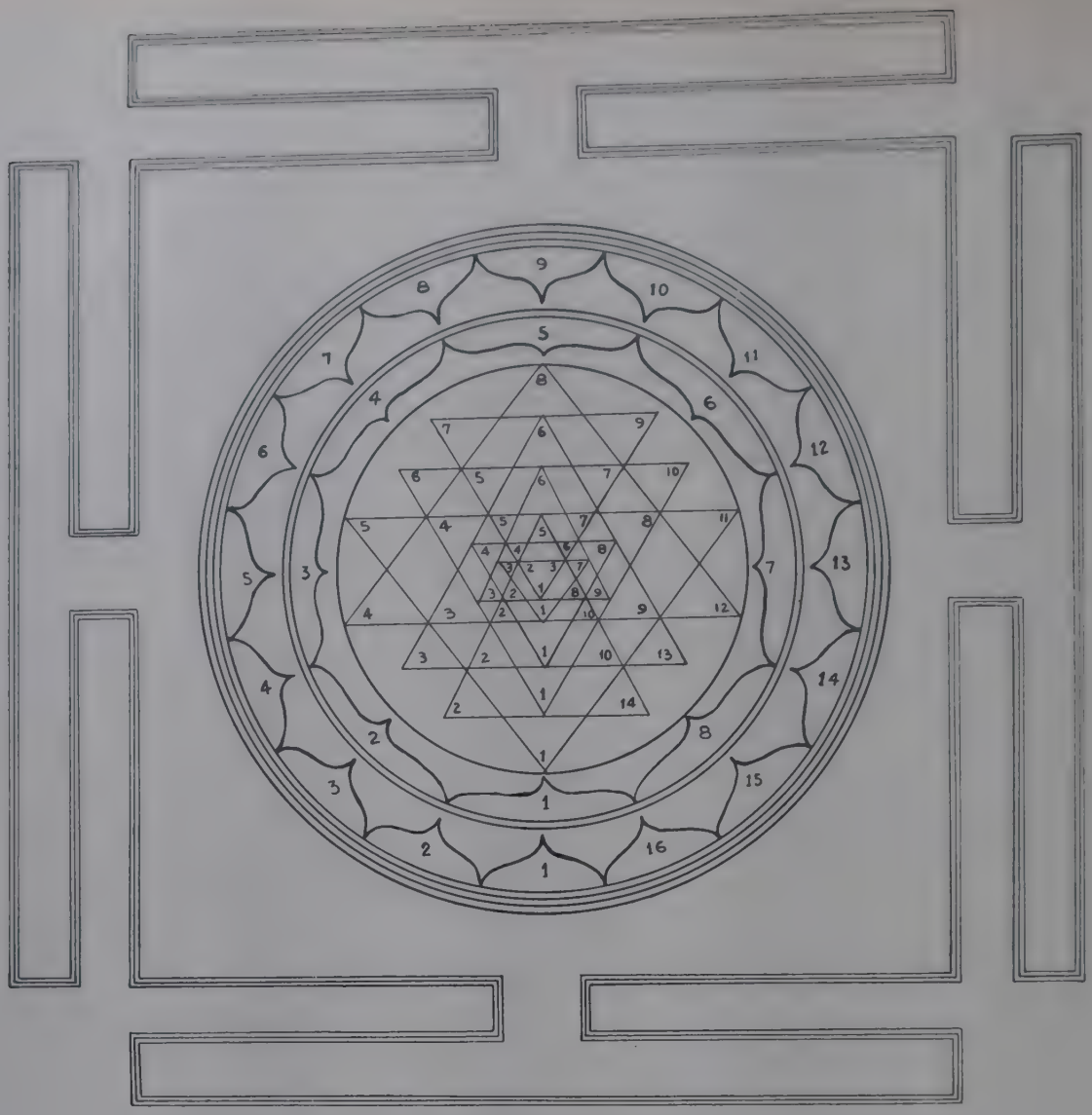


Fig. 19

Shree Yantra

There are two kinds of Presentation of Shree Yantra, The Configuration of both are identical except that the Central tetrahedron in two Cases are in Opposite Phases.

configuration of Yantras and Chakras etc. This invariably would provide insight into the fact that their basis has been tetrahedral evolutionary concept just as the equilibrium configuration of the universal spherical wave which oscillates between two extreme opposite limits of states of central point state and spherical boundary. In the universal wave, the configuration of the wave in one direction may be taken and the variation of the various dimension in one direction of the wave can be considered with relevant resulting configuration in one direction. Then again, instead of considering the universal wave as a whole, certain aspects within the homogeneous zone may be considered and analysed. Similarly, an aspect in the heterogeneous zone also may be analysed. While considering those appropriate configurations with reference to the context of the configurations of the whole universal wave can be made and referred to. The various Yantras and Chakras, many of which have not been discussed in the above, must also have been related to certain aspects of concept which need not always be a whole concept like the whole configuration of the universal wave.

The above discussion should help in providing guidance to plan further investigations and research on the real physical significance of the various Jantras and Chakras and their configurational relationship with the configuration of the universal wave. For example, one can straight away start analysing the configuration of

Sri Jantra with its usual configurational characteristics in the background of plane equilateral triangular graph paper. This has been shown in figures 19(a). It should be remembered that the Shree Yantra as such has two main configurations in which all the rest of the configuration in the two are same except the central smallest equilateral triangles which are in opposite phases in the two configurations. If both the Sree Jantras would be converted into one configuration, all that would happen is that there will be two central tetrahedrons in opposition as Sat Chakra as has been shown in the figure 19a. Let us now consider the mechanism. Here there are altogether 5 pairs of equilateral triangles in opposition. Each of the first biggest pair in opposition has its centre of the triangular face coinciding with the mid point of base side of the other in opposite phase. Each of the second biggest pair in opposition has mid point of its base side coinciding with the mid point of median of the first biggest in opposite phase. Each of the apexes of third biggest coincide with mid points of base side of the first biggest in opposite phase. Each of the third main pair in opposition its mid point of base side coinciding with apex of second biggest in opposition. The fourth (in dotted lines) main pair have each of their apex positions coinciding with the mid points of median of first biggest in opposite phase. The pairs of triangles in opposition in dotted lines (which represent the equality equilibrium in the configuration of the universal wave) are obtained by joining the mid point of sides of the second biggest pair of triangles. The central pair of triangles in opposition have their centres coinciding with centre of the Shri Jantra configuration.

It may be noted that the vertical distance between the opposite apexes from the centre is 20 units of smallest medians and the horizontal outermost position has only 10 smallest of sides. On either side of the vertical direction through the apex and centre there are altogether 16 Granthi or Marma positions equidistant from the centre which would correspond to the 16 outermost petals as co-ordinates between two positions of the Sri Jantra. With respect to horizontal direction, through centre and 10 Sandhi positions there are 8 braces or petals between alternate realised apex positions.

**Significance of the outermost 16 braces and inner 8 braces surrounding the Sriyantra**

The Sreeyantra as presented in figures 19(a) and 19(b), will reveal that the mid points of the straight lines joining any two adjacent apexes of outer cone, always coincide with one Granthi (ग्रन्थि) position. Besides XX there are 14 such positions and in the three directional concept (conventionally three dimensional) each of inner braces comprises of three positions and the total number of such positions of braces are 8.

Again with respect to the distance between two apex positions as diameter there are obtained 16 Granthi positions at equal radial distance from the centre. In

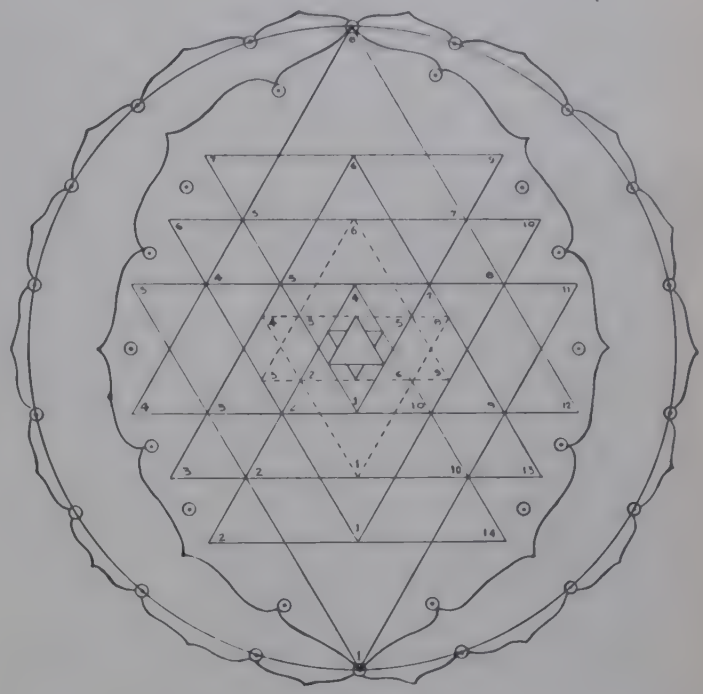


Fig. 19(a)

Shree Yantra in One Configuration with the Central tetrahedrons in Opposite Phases showing analysis of brackets.

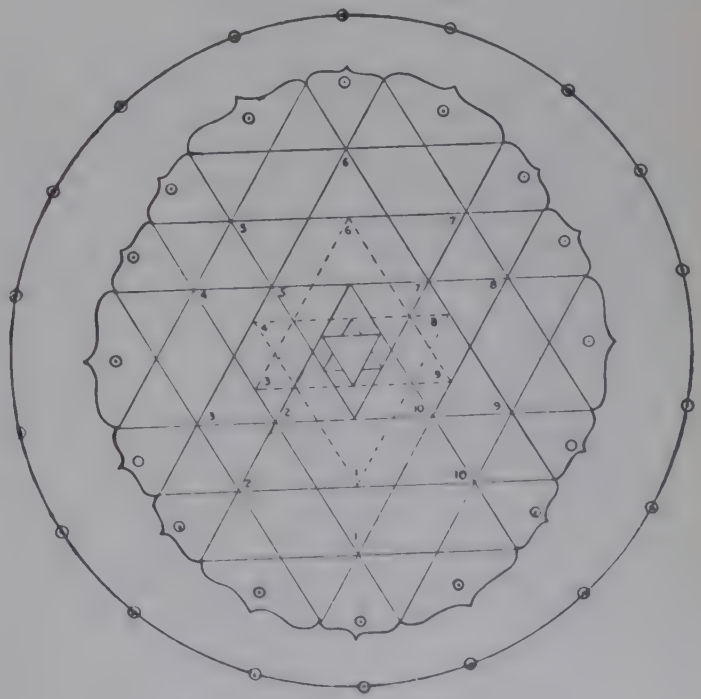


Fig. 19(b)

two directional concept each of the outermost braces would cover two positions. Further all these 16 granthi positions in the outer circles are positions at equal radial distance from the centre. There are 14 cones in the inner circles which are due to the sides and extensions of the apex positions of the equality equilibrium triangles. But the outer triangular positions are due to extensions of sides of biggest triangles in opposition, and extensions of the sides of the equality equilibrium triangles and also extensions of the apex positions of the centre-most triangles.

The significance of the braces would be more clarified in the figure 19(b). Here when two opposite apex positions XX of the biggest triangles of Sree Yantra are eliminated and instead substituted by two pairs of positions in opposition, the resulting configuration yields all the 16 outermost triangles of equal magnitude indicating the 16 evolved tetrahedrons of the universal wave surrounding the central configuration.

Further analysis would bring out the identity of the configuration of Sree Yantra as universal wave as presented on equilateral three directional triangular graph with the actual 4 directional tetrahedral spatial configuration of the configuration of the universal wave.

The essential aspects of Sree Yantra lie in its conventional figures having two sets of opposing equilateral triangles with respect to one common centre. Although the analysis given before in figure 19(a) and 19(b) in three-directional co-ordinates of a plane, the equilibrium combination of the two-conventional figures actually would indicate the presentation of the configuration in two directional squared graph paper on a plane which has been shown in figure 19c. The significance of this configuration which was also one of the main Yantra in Tantra called Sarbatovadhara Yantra was mentioned previously in figure 18. The universal configuration has central tetrahedron surrounded by 16 outer tetrahedrons. The central tetrahedron, when placed vertically on one side and looked from top, the projected diagram is that of a square which has been shown in many figures before. The central square ABCD is the configuration of the central tetrahedron and in the outer zone of the universal wave, there are altogether 16 tetrahedrons, 4 in each direction in the representations on squared graph paper the central tetrahedron is surrounded by 4 equal squares in each direction. If each smallest square is taken as the unit square, the 16 tetrahedrons are indicated by these 64 unit squares but taking the central square making complete universal wave, the 4 squares at the boundaries (dotted lines) actually represent the central tetrahedron which in the evolutionary of the heterogeneous field has imaginary existence. Thus between the equality equilibrium and the boundary, the entire configuration including the 4 square units within ABCD would have to be taken into account.

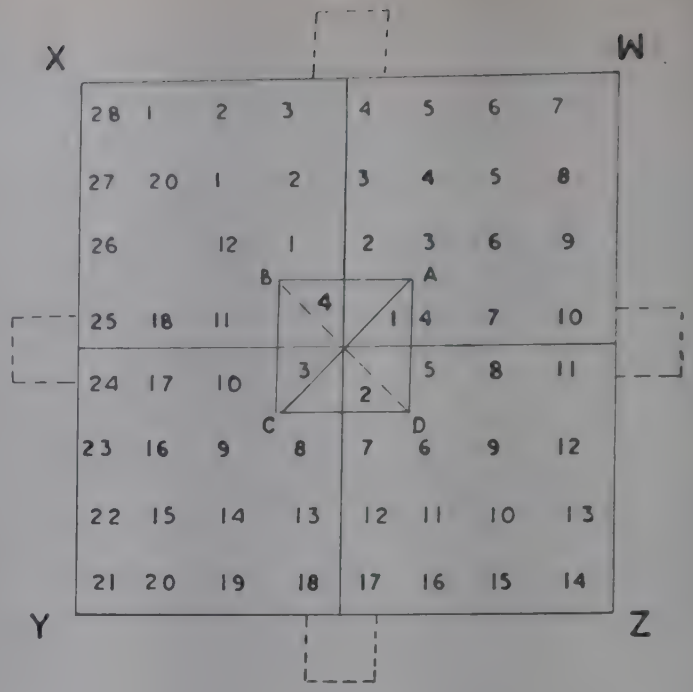



Fig. 19(c)

**Significance of modern periodic classification of elements in the light of the configuration of universal wave as well as the configuration of Shree Yantra.**

The presentation in the squared paper in figure 19(c) relative to development in heterogeneous field context of the universal wave would follow the following cumulative sequences as multiples of 1, 3, 5, 7 . . . depending upon the number of directions in the configuration.

Cumulative for two opposite directions:—

$4 \times 1^2$ i.e. 4 times one square.
$4 \times 2^2$ i.e. 4 times two squares.
$4 \times 3^2$ i.e. 4 times three squares.
$4 \times 4^2$ i.e. 4 times four squares.

The series can be split between opposites as follows:

2, 2: 8, 8: 18, 18: 32, 32: and so on

Needless to mention this is the same as the periodic classification of elementary matter as has been discovered in modern science but the aspects of 2 and 2 in the first series are not clear in modern science. An explanation has been made to clarify significance in terms of discoveries in science.

The clarification of the 2, 2 in the first series of elements has been made in the work "Energy Field of the Universe and Atom", Part II.

It is recognised that the discussions about Sree Jantra and explanation of its configurational evolution may not be clear from the previous discussions on it. The first reason is that conventional presentation of Sree Yantra is distorted as well as it is incomplete. The correct configuration has been shown in figure 19(a) and 19(b) in the configuration of 3 directional plane will clarify somewhat about the real nature of the final configuration. In figure 19 (d) evaluation of the Sree yantra configuration has been attempted to be explained starting with two tetrahedrons AAA and aaa in opposition as shown in the figure. The triangular faces $AO_1O_2$ or $ao_1o_2$ would each represent triangular face of the central tetrahedron and the equilateral triangles AAA and aaa represent 2 tetrahedrons. There are 3 tetrahedrons in one direction surrounding one tetrahedron face to face with respect to the central tetrahedron. So when these two oscillate between opposing phases the two tetrahedrons AAA and aaa would correspondingly add more tetrahedrons into their faces. The circled points of AAA and aaa with the magnitude of the sides which described additional circled points of positions are indicated in the figure. Similarly, squared points of the triangles aaa

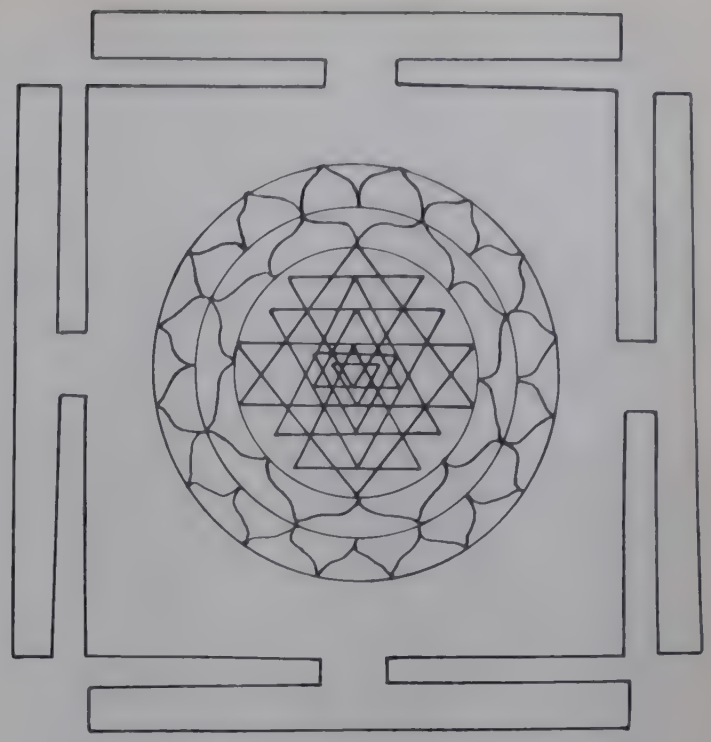


Fig. 20(a)

Sristhi Krama (सृष्टि क्रम) worshipped by the pupils of Samyachar School.

(5 Shakti triangles-vertically upwards 24 Shiv-triangle—vertically downwards).

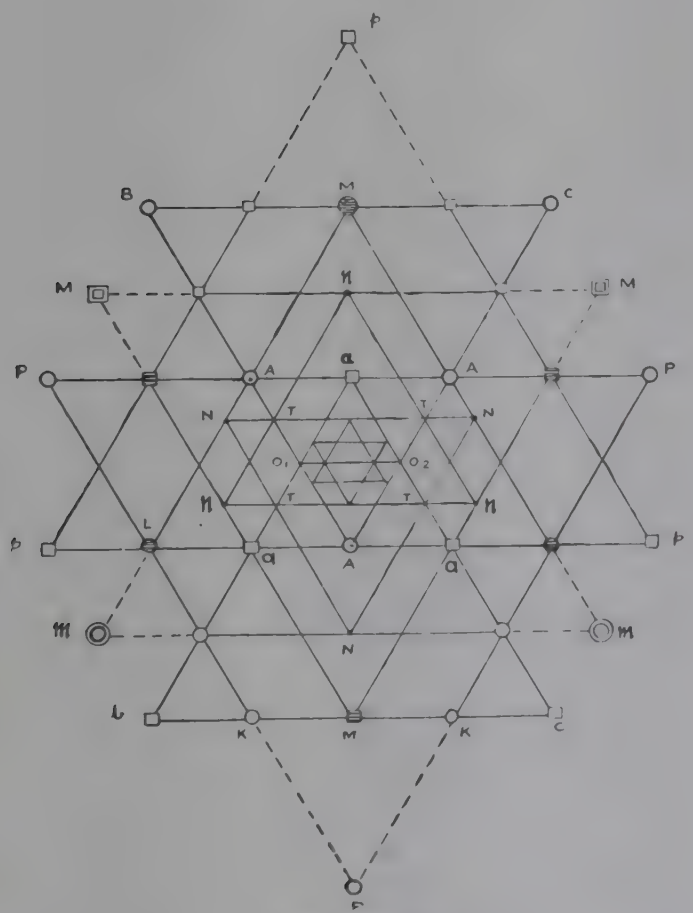


Fig. 19(d)

would have other squared points of positions which would create two tetrahedrons to make the configuration complete in two directions. The new sets of positions develop two biggest and smallest triangles viz. PPP, ppp and ABC and abc.

The reverse path followed in the configuration may now be described. Triangle mmm, MMM have been constructed as equilibrium average in size between the biggest triangle PPP and smallest triangle abc. The next step is to find the equilibrium configuration between MMM and mmm which is obtained by joining their mid points. These equilibrium triangles NNN and nnn now develop positions like TTT which, in association with the original position Aa makes the configuration a regular octahedron. The average half of this finally makes the centralmost tetrahedron in opposition making the configuration a regular octahedron of cube.

Numerical aspect of the development of Sree Yantra as depicted in three directional triangles shows how development of tetrahedrons in one direction as 1, 3, 5, 7

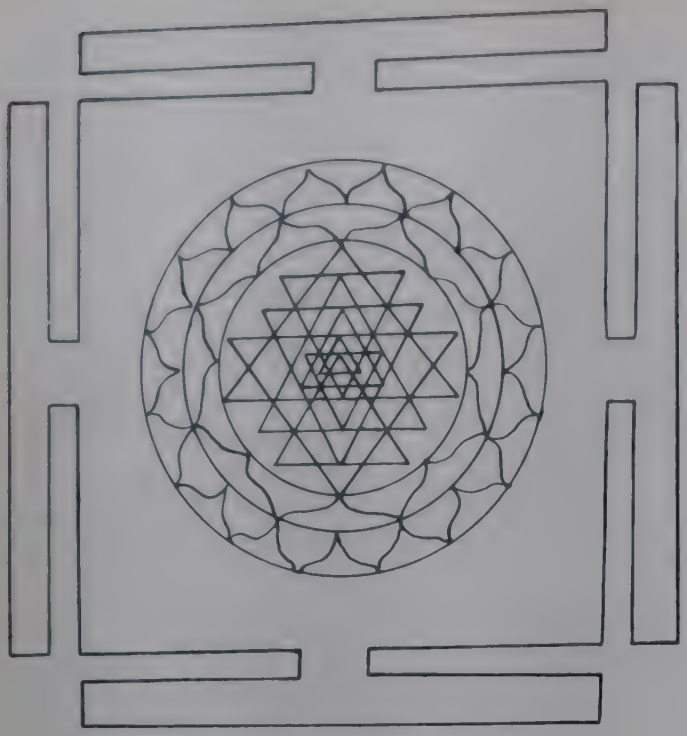


Fig. 20(b)

Shanhar Krama (संहार क्रम) worshipped by the pupils of Kowllachar School.

(5 Shakti triangles-vertically downwards 4 Shiva-triangles-vertically upwards).

and so on follows. The significance of two sets of configurations of Shri Jantra indicates development in four directions which are as follows:

$$4\times1,\ 4\times3,\ 4\times5,\ 4\times7.....$$

The cumulative effects of these also are the same as was found by the presentation of universal wave in the heterogeneous zone in the squared graph in figure 18 or 19c.

**Why the configuration of evolved universe used to be called as Brahmanda and not Brahma Golak?**

This is an important aspect of configuration of evolution. Anda means egg and Golak means sphere. In the works entitled "Energy Field of the Universe and Atom", Part II, Fig. 34 and Figs in 5m and 6a of space time configuration, Technology Vol. 4, No. 1, 1967 it was shown that the energy-matter evolution from a point position takes place in tetrahedral direction. There are four probabilities; meaning that there are four possible directions of evolution. In one direction in evolution equilibrium configuration would be generated by 109° three directional tetrahedral space time coordinates from Centre, which will be opposed by a 60° three directional coordinates, face to face from the boundary. (Ref. Fig. 5K. and Fig. 34, Part II, reproduced below.) If variability will be associated with the positions along directions, naturally the shape that the configuration will take would be like that of an egg and not perfect sphere. The significance of configuration of Universal evolution which was termed as Brahmanda (Egg of Brahma) lies in this statistical evolution of the universe in one direction used to be called as Brahmanda (as shape of an egg) and not Brahma Golak (Sphere).

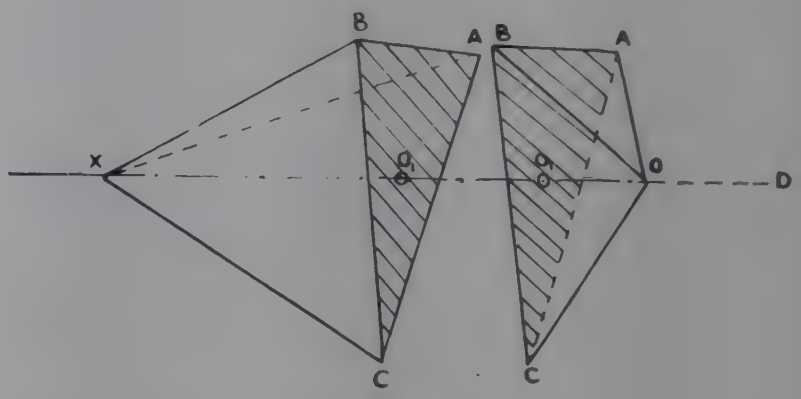



Fig. 21(a)

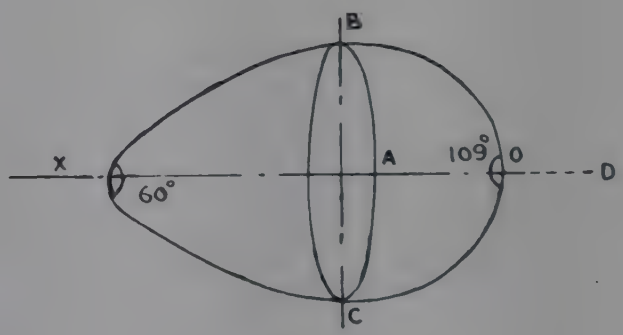



Fig. 21(b)

If however 4 directions of evolutions would be taken into account the locus of positions XY and Z would be on spherical (but tetrahedral) surface locus with O as the Centre.

**The Finite Universe Caused by Fundamental is Perceived essentially through Derived Dimension.**

Fundamental dimension energy in its abstract state has no configuration. It only assumes a configuration by association with derived dimension like matter which gives the configuration of energy matter equilibrium as

universal wave. So long as the derived dimension does not get associated with fundamental, configuration also does not evolve. The previous phenomenon is not amenable to perception. Perception only occurs when there is configuration. The configuration of fundamental energy does not materialise unless in association with matter. Therefore, in this world of perception actual realisation of the phenomena occurs through the derived dimension and the evolved configuration. This can be further clarified. The positions of evolved configuration, says, tetrahedron can be seen in two ways: from position at centre or from one of the evolved positions of the tetrahedron. Former is direction of fundamental and the latter is that of derived. Therefore, perception of the configuration by one equivalent to derived dimension must be through evolved position in the configuration. For the generation of the universal wave the association of derived with fundamental and the configuration subsequently developed is most important. The whole configuration cannot be generated if the fundamental dimension was not in association with derived throughout. Prakriti of Sankhya refers to derived or material and configurational aspect. Purusha (पुरुष) concerns the radial aspect of fundamental dimension of the configuration. While applying the basic principles to Atman Indriya (इन्द्रिय) dimensional concept of combination, Atman like the fundamental dimension energy is self-emanating and possess radiating property. Atman signifies consciousness. The mind as Manas (मानस) Indriya (इन्द्रिय) is like derived dimension of matter as Yada (यद्) having contracting property. Matter without energy cannot form configuration. Mind too without consciousness remains dormant. Without association of consciousness it would be dead or dormant Indriya. Atman and Manas Indriya (मानस इन्द्रिय) are opposites, just as consciousness as Chaitanaya (चैतन्य) and dormant Yada (यद्) are opposites.

Some mis-conception about Kapila's Sankhya was generated subsequent ages and doubt arose leading to the ideas that Kapila's Sankhya believed only the yada aspect of Prakriti and that the whole approach is Nastik (नास्तिक) i.e. it does not believe in the existence of the Atman consciousness as the supreme. This also gave rise to the interpretation that Kapila in Sankhya treated Prakriti and Pradhan as fundamental dimension and not the Atman and its mahatta. In order to understand the evolution one must understand the evolutionary configuration of the wave which must be due to association of fundamental with derived dimension like matter and energy or Yada Prakriti with consciousness or such other appropriate dimensions chosen for the fundamental and derived. Actually in Kapila's Sankhya total concept remains valid and is identical in significance with that of the universal wave due to two opposite dimensions in association to have the configuration of the Universal wave. All these discrepancies and doubts as well as misconceptions will be removed if analysis of the various manifestations (which involve opposite dimensions—one of which is fundamental and the other is derived) is made in the light of the standard configuration of universal wave following the postulates of the basic law relating to the configuration and constitution of the universal wave in association with variability aspect in proper perspective. The controversies regarding whether there can be Bahu Atma (बहुआत्मा) or Single Atman or whether Pradhan relative to Prakriti as fundamental or Mahat (महत्) relative to Purusha as fundamental, will be solved once all these aspects are analysed taking into account the mechanism and significance of the configuration of the universal wave.

**Present situation in the Modern World**

It is not intended to go into further details in scrutinizing the various dimensions involved in different concepts in the ancient philosophical approaches in India in the light of the universal wave. We shall however in the following make an attempt to analyse the situations that are relevant in present social, political and intellectual context in the modern world in the light of the postulates of universal wave.

From the significance of various dimensions in an equilibrium concept which would be construed, it can be easily realised that Mahatta (महत्त) or greatness can also be nobleness, selflessness of the Soul with highest intensity at centre while Pradhanatta (प्रधानत्त) whose highest magnitude of size is at the boundary, can relate to the derived as Indriya (इन्द्रिय) whose highest magnitudes of intensity would be at the boundary, where the Ahmatta (अहमत्त) or Ahankar (अहंकार) of Indriya is also highest. Instead of Ahamatta or Ahankar, it could be selfishness or egoism. The centre of the universal wave would have these latter properties of least magnitudes where the intensity of the fundamental is at its finite highest and wherefrom when it gets rid completely of derived opposite dimension, it attains a state of infinite magnitude of purity unassociated with material or selfishness content.

In the light of the universal spherical wave, magnitude of greatness of soul is highest at the centre with least association of Ahankar, selfishness, self-comfort etc. Away from the central, material association of fundamental increases progressively towards the boundary

where greatness progressively loses its intensity and magnitude to material interest of Ahamatta or Ahankar increases to highest value. The higher the magnitude of Mahatta (महत्त) of soul associated, the lower is the magnitude of selfisheness of Indriya associated with Mahatta of soul. The association of these opposites in the homogeneous field of the wave is an equilibrium combination in which two opposites are in one inseparable. This is Dwaita (द्वैत) state. But fundamental in Absolute or (isolated) abstract state of infinite purity is Adwaita (अद्वैत) concept. The latter is the state of Ekam Evam Adwitiyam (एकम् एवम् अद्वितीयम्) In association, two at the equality equilibrium are equal in magnitude but in the hetergeneous equilibrium the two separate out the derived dimension assumes a different configuration and separates out in different phases from the mother phases containing the fundamental which gets gradually depleted in intensity of its content towards the boundary; while the seggregated configuration containing the derived, progressively increases in its magnitude of intensity of its content towards the boundary acquiring highest magnitude.

**The Eternal Question**

*What should be Ideology of Life and Civilization?*

The basic laws of the Universal Wave can be applied to answer to eternal question: what should be the true ideology of life and the true meaning of civilization and culture?

From the configuration of the universal spherical wave the following main states and directions of ideologies can be reckoned with:

(a) The state at the centre is a state of unadulterated purity or infinite intensity of fundamental of Mahatta of Atman. This state of fundamental dimension can be arrived at only by progressively getting rid of the derived dimensions of Ahamatta or selfishness, self-comfort of Indriya etc. This is an abstract static state but a state of calmess, self-reliance, self-sufficiency etc. This is a state of Param Mukti or Moksha.

(b) If the objective is towards the boundary state of existence, where fundamental loses all intensity and drived predominates and greatness or nobleness loses all significance, what dominates is self-comfort, selfishness, personal ego and so on. This is a state which is also static but is a lazy and stagnant state of existence.This is a state comparable to state of sleeping or Susupti (सुषुप्ति) of indriya.

(c) In between the boundary and the centre, there is the state of equality equilibrium in the universal spherical wave where the opposing dimensions are of equal magnitude. At this region all irrespective of their potentials are valued alike and no differentiation is made between selflessness on the one hand and selfishness on the other. In the universal spherical wave theory, this is a state of infinite variability which signifies a state of restlesness, ficklemindedness and a dynamic state of chaos and confusion where one is not sure in which direction to move to achieve the true ideology.

Interpreted in terms of everyday life, the second state is a static one of highest material interest and of lazy idolence of Ahankar, Selfishness etc. The third state is one of chaotic existence where ethics, principles, values, merit etc. have lost their significance and only confusion and chaos prevail. The first is the state of absolute calmness at which only nobleness prevails and all degrading dimensions are eliminated. Between the centre and the equality equilibrium is a state of existence where the two dimensions exist as one in unity unlike their existence in separate forms in between the boundary and the equality equilibrium states.

In thermodynamical terms, the equilibrium state of equality is a state of maximum entropy and maximum probability where anything or everything is possible. The centre is the state of least entropy (in the positive sense) related to fundamental. The state at the boundary, with respect to the derived dimension or selfishness, is also the state of least entropy (in the negative sense).

Choice has to be made as to which direction should civilisation and culture strive for and what the aim of individual life or civilisation should be. The application of and deductions from the original Sankhya theory, as revealed in various schools of philosophy developed in subsequent ages, it is universally accepted that the ideal approach, which the universal spherical wave dictates, should be towards the one and only direction towards the centre and towards the achievement of the highest Mahatta (महत्त) of the soul towards the state of Paramatman/Parambrahman (परमात्मन्/परमब्रह्म) which is the absolute abstract state of pure consciousness completely released (मोक्ष) from and unassociated with any opposite derived or containing dimensions.

The above analysis also gives us a lead to discern what are the different nature of happiness, comfort and pleasure that one may experience and what is the nature of civilisation should we all aspire for. The approach, it is agreed, should be from the boundary towards the centre and not in the reverse direction which is a retrograde step. Approach towards the centre in our individual mental attitude or in social attitude or even in international political attitude must be guided by this

principle. To make this approach clear and easier for understanding it can be illustrated in the following:

Take the case of a new-born child of a poor mother. She herself does not have enough material or food to sustain herself. Whatever food she could get, herself remaining starved, she gets pleasure and happiness by feeding that to the child. The mother though herself remains starved, by seeing the child happy, at the cost of her own starvation, derives pleasure. This is one kind of pleasure and happiness. Take another example: suppose there are two hungry individuals and there is some food available to them. One of them grasps the whole food, satisfies his or her hunger and becomes happy and becomes comfortable at the cost of the starvation of the other man. In the latter case the other individual continues to starve and remains unhappy. The two approaches are exact opposites. In one case the happiness is derived at the cost of self-suffering and self-sacrifice, (as in the homogeneous zone in the universal wave towards the centre) and the second approach is to get satisfaction and pleasure by seeing the other unhappy and suffer (as in the heterogeneous zone towards the boundary).

Needless to say that the direction of ideology of civilization if applied to individual cultivation of happiness etc. that would be the one which would cultivate and approach from boundary of the universal wave towards the centre thereby derive happiness, comfort peace, pleasure etc. But that should require to derive happiness by adopting an attitude whereby others are happy and comfortable and at the cost of his or her self. One has to sacrifice these things relating to his or her own. This must be the fundamental law of civilization. The reverse process of deriving pleasure, comfort etc. which results in other's unhappiness etc. must be retrograative process in civilisation in the world. Herein lies the essence and objective ideology of human civilisation. Once this principle is understood in all aspects and in proper perspective and is accepted by all, there should not be any problem or conflict in the equilibrium existence of individuals, societies and nations in the world. These principles were cultivated in this land in the past both in theory and practice, as would be revealed in almost all philosophical dictum in ancient India including the principles enunciated by Budha, Mahavira, Christ, Sankara, Mohammad, Chaitainaya, Ramakrishna and Gandhiji at different times.

**The situation which prevails these days**

Looking at the conventional life as it exists in the present time and the direction in which civilization is proceeding, there can be only one unanimous conclusion that the ideology of achievement towards one at the centre does not exist any more and as such, such an approach does not inspire any of our actions or way of life neither in individual nor in national or international spheres. These days, the only dominant ideology which is entertained is the pursuit of selfish and ambitious ends for comfortable living, bargaining for better material prospects and strife for freedom from any material or physical suffering. Virtues, merits and values in one's everyday life and the socalled standard of living are wholly and solely determined by these objectives. The ideology towards high thinking and plain living, sacrificing self-comfort for the benefit of others, foregoing material benefits for other's enrichment, assiduously cultivating elevation of one's own self towards a state of selfless existence in a spirit of self-sacrifice is not only wholly absent but such attitude is jeered at as unrealistic, impracticable, foolish or even tendentious. Efforts in the direction of self control as taught in Yoga (योग) and elimination of degrading dimensions towards elevating oneself to nobleness is entirely meaningless today. Approaches in almost all spheres of individual, social and national life are material and selfish.

To give an easily appreciated common example, every parent today has only one thought for the future of his child and that is to assure his bright future related to material prosperity, completely unconcerned with the simultaneous improvement of the child towards selfless existence and towards nobleness. The tutoring of the child had noble aims in the olden days through such processess as the Upanayana (उपनयन) Brahmacharyyam (ब्रह्मचर्य) Pranayam (प्राणायाम) and Yoga (योग). These are the processess which also are dictated by the principles of the universal wave. Today these have lost their true meaning and significance and have become mere empty rituals. In fact, these traditions of old are given a bad name today as perverted approach to life; they are branded as unnatural on the ground that they do not give full freedom to the individual for 'free' action.

The approach that man should be given full freedom (which is only material or physical) to act according to his propensities and inclinations in an uncontrolled and unbridled manner reduces human beings only to the level of beasts or a state of chaotic existence. The essential difference between man and beast lies in the probability of cultivation of the human faculties to control those and to rise to the highest state of greatness. The present approach only reduces the probability of status of human beings to be degraded to the level of beasts. The direction is bound to be only towards a beastly state of existence—a state of maximum

entropy and chaos or towards negative entropy state of utmost degradation of soul. The ideology of our present civilization is this.

All of us live today in a state of utter chaos. Though we profess that civilization is advancing, since there is no ideology for the cultivation of selflessness, there is hardly any positive or true ideology in our civilization today. All individuals in all situations are allowed freedom of action in any direction. There does not exist any discipline or control or rule of law or justice or evaluation of and respect for the human individual in terms of merit and greatness.

Juvenile delinquency is a universal phenomenon these days. This has come about mainly because of the present chaotic state of approach in civilisation in which man has lost his way from true direction towards ideologies of truth and justice. In the educational curriculum, the children are not imparted any lesson or teaching of what Truth is, nor are they asked to practise any traditional ritual towards the cultivation of self—towards the ideology of Truth or towards realisation of the Absolute. Though such practices were invariably practised in the past but that requires self-discipline in order to rise towards realisation of true values. On the contrary, there is positive discouragement of such practices. Children are encouraged to act according to their whims or are allowed freely to react to circumstances which they face in any manner they like. Therefore, the natural effects of environmental circumstances completely uncontrolled, play the dominant role in shaping their attitudes and their actions in society.

The same attitude is discernible in the approach towards the solution of the problem of population control. All the remedial measures suggested or adopted refer only to artificial mechanical contrivances, which are entirely physical, thus retaining the material basis of enjoyment of the physical senses, which are given free rein. There is absolutely no serious thinking or firm resolve or concerted acton on the exercise of moral self-control and self-denial, these being moral and spiritual values which everyone is aware, have been extolled in all the ancient scriptures in this country as the most noble code of conduct through practices of self-control such as Brahmacharyya (ब्रह्मचर्य) Yoga (योग) etc.

**No Differentiation of Values**

The chaotic situation through which the civilization in the entire world and its intellectual status is passing through suffers from lack of definite positive ideology of life. Material power is dominating the scene in society; personal and individual attitudes are full of retrograde attitudes which act in direction opposite to that of fundamental and works in opposite direction towards achieving status of selflessness. The good attitudes and qualities are not considered better virtues than working for selfish ends. Killers and Killed, criminal and the victim, the outstanding worker and the idler, meritorous and worthless have lost their relative significance. In other words, gradient according to positive potentials of virtues which is universal law, has lost all significance.

In present times, in modern science, the derived dimension matter is given and treated with the status of fundamental dimension while relagating the true fundamental dimension energy to the position of derived. Further in modern scientific laws matter is not considered in simultaneous combination with energy and vice versa. Matter is even considered capable of isolated independent existence from fundamental dimension energy. Repercussions of this misplaced assumption not only have dominating misleading influence in the basic principles in modern science but have also percolated down in thinking in all spheres; individual, social and national throughout the world.

Positions of authority and control must be occupied by one equivalent in significance of fundamental dimension. But it is often positioned by those who are dimensionally opposites as destroyer or exploiters. Many who are not even fit to be disciples are bestowed with power of material authority and position and thereby undermine those under their control, who possess status of preceptor.

In this chaotic state, it is not surprising that each and everyone, irrespective of individual calibre or potential of achievement, insists on equality of rights for recognition, for claim for possession of material status and for the so-called birth rights. These social attitudes are further aggravated by the natural reactions of the community to the evils inherrent in the domination of the community by those possessing over-riding material forces occupying controlling stations in life and possess the utmost concentration of power and wealth at the cost of others. This approach towards life is diametrically opposite to the cultivation of oneself towards the elevated state of selflessness and this is invariably a process which is wrought through the exploitation of others forcibly rendering them to a state of relatively helpless and hopeless existence.

**Gandhiji's Idology of Non-violence**

The essence of Gandhiji's teachings in his philosophy of 'non-violence' lies in the true attitude to life. A man

may be hurt in some way or other by another. The reaction can be two-fold. The first reaction could be whatever may be the reason for the hurt, intentional or unintentional, motivated or without motivation, the attitude of paying back in reply to the action in the same terms and thereby try to teach a lesson to the alleged offender. The other reaction could be to react with an attitude of forgiveness to reform by appeal to the offender not to indulge in it. Reformation of the attitude of the offender is not possible by the first approach. But by the second, it is possible; but this requires courage and conviction of the victum to rise in greatness and nobleness to stand the sufferings due to aggressive action of the offender and to have also the courage to persuade the offender to reform. The first approach is the one by which Gandhiji meant "violence approach" and the second attitude is "non-violence". In the theory of universal wave of "Energy field of the Universe and Atom", the true direction of ideology which has been enunciated before towards cultivation of self as soul towards higher greatness is the attitude of "non-violence". The cultivation of physical self by sacrificing moral virtues at the cost of others are all attitudes which emanate from attitude of violence.

**Enunciation of true ideology of life and civilization**

In our so-called civilisation today, we are living in times where moral ethical values of soul have been discharged and where improvement of physical self as Indriya alone is the prime consideration. In our education, our thinking and our avocations, we only aspire for a bright career, for assured material prospects and for assured physical comfort. On the other hand, the values accruing from obtaining supreme satisfaction, through self-suffering and self-sacrifice, as for example, starving one's self for feeding a hungry man, sacrificing one's own for other welfare and enjoying his own sufferings by seeing others benefited, have little meaning these days. As said before, these attitudes are mocked at as unrealistic, impracticable and even foolish. It is indeed high time for all to make a real assessment of the situation and to decide what the correct direction of ideology should be and in what direction the objectives of life and progress of civilisation should be.

We must have now to find a way out, from this state of chaotic situation in almost every affair that concerns ideology of individual and national life, how to establish true ideology and how to cultivate ourselves in that direction. We have seen and have been experiencing the disastrous results of cultivation of aim towards happiness of self-comfort, self-profiteering and everything concerning physical and material self. In the olden times the general ideology in this country which endured for long time, and stood the effect of time was towards cultivation of ideology of attaining happiness and pleasure by adopting the ideology of deriving happiness by seeing or making others happy at the cost of self denial. Though this is the true ideology it has been forgotten. It requires to be revived. To become happy in individual life and in the national attitude by making others happy at one's own cost or by ways and means which may lead to apparent sufferings of oneself in this physical life should be our true aspiration and motto. We have to revive and re-establish that status of ideological consiousness and wisdom in our civilization.

The present situation demands thorough reformation. To bring about a world-wide reformation in the direction of ideology of individual and national life out of utter chaos, however, is a formidable task. The situation, therefore, demands the advent of highest consciousness and wisdom potential which must come down to help and rescue the values of truth, merit and justice. There is no other way out. We are exactly in the situation wherein is applicable the principle of famous slokas in *Gita*: Ch. IV:

यदा यदा हि धर्मस्य ग्लानिर्भवति भारत ।
अभ्युत्थानमधर्मस्य तदाऽऽत्मानं सृजाम्यहम् ।।७।।
परित्राणाय साधूनां विनाशाय च दुष्कृताम् ।
धर्मसंस्थापनार्थय सम्भवामि युगे युगे ।।८।।

(धर्म) Dharma here does not mean merely any religion as it is conventionally taken to be. It means the rule of law and justice, the acceptance of and respect for positive potentials of virtues in terms of this natural gradient; when these cease to exist, to correct the situation, advent of SOME supreme consciousness and widom of highest magnitude of potential, as fundamental dimension signified by Aham (अहम्) is necessary to enlighten all and re-establish the correct gradient as per enlightened individual potentials.

In this formidable task of reformation, those who would care set themselves to the task of contributing their mite have to take a solemn vow to dedicate themselves to the cause, absolutely selflessly without any expectation of fruit whatsoever in return for their sacrificial service in the true spirit of the sloka in Gita as: Sloka 47 (Ch. II):

कर्मण्येवाधिकारस्ते मा फलेषु कदाचन ।
मा कर्मफलहेतुर्भूर्मा ते सङ्गोऽस्त्वकर्मणि ।।

This signifies:

> "Your right is to work only, but never to the fruit thereof. Let not the fruit of action be your object, nor let your attachment be to inaction."

Dictates of the basic postulates of Universal Wave would thus lead to the following precepts of ideal culture and civilisation in individual, national and international spheres:

1. Ideal happiness in human life is one which is derived as a result of efforts and work with devotion and conviction and faith to make others benefited, helped and assisted unimpressed with self-desire and that at the cost of sacrifice of one's own self-interest.

2. Cultivation of this precept in practice in everyday life in attitudes and approaches in all individual and social contexts must be the sole criterion of ideal culture which is bound to lead to an ideal society of individuals and their civilization.

3. Status of individuals must wholly and solely be guided by the magnitude of self-denial and its potential of capacity to impart benefit to others.

4. In all approaches mankind must observe respect for superiority of potentials and must respect each individual's relative position in order of their potential gradient of status.

5. All individuals desirous of improvement of status of their self must work and conceptrate upon these principles in theory and practice.

6. Direction of gravitation of friendship and comradeship must lie in unified actions of individuals and which must be towards attainment of higher potentials of higher status.

7. Highest authority to administer must only rest in one who has attained the higher potential of capability by retaining nothing or nil for self can contribute all for the service of others and who is most isotropic and judicious in administration of distribution of favours, benefits, happiness etc. according to potential gradient.

These are the dictates of universal wave to ideal human civilisation which all must aspire for.

# Thermodynamics and External Agency

By

K. R. Chakravorty,

*Planning & Development Division,*
*Fertilizer Corporation of India Ltd., Sindri, Bihar*

According to the second law of thermodynamics heat cannot be transferred from a lower to a higher temperature without the help of an "external agency". It stipulates that every system in nature, left to itself, changes towards a final state of equilibrium. In the modern technological age, there are few other engineering rules of fundamental importance which have been so extensively used as the Second Law. But there has not been much concerted effort so far to probe into its fundamental applicability in areas other than purely applied engineering. In the following sections are presented further discussions on deductions made from the Second Law of Thermodynamics. The existence of a superior external agency is a sine qua non in the universal context and in the various manifestations and occurrences in Nature. The discussions also deduce the dimensions that have necessarily to be attributed to such an external agency. For example, (without the help of external agency if a quantity of heat cannot be raised from a lower to a higher temperature) what exactly is the external agency required? What precisely are its nature and functions? While the second Law requires performance of work by an external agency to transfer heat from a lower to higher temperature, the fundamental question that requires answer is: whether material energy alone is enough for the performance of work required by the second law of thermodynamics? If so, then, could not our civilisation and materialistic development take place without the help of any other external influence? The very fact that the living beings have always been directly involved in building up of civilisation demands a deeper probe into the significance of the functions of the "external agency".

We may consider this from an example in modern context. A modern factory manufacturing a desired product can only be built by efforts of engineers and technologists based on not only their knowledge and intelligence *but also on their will to put up the factory.* The structural materials for the factory to be built and the raw materials from which the final product will be manufactured might all be available at various places; so also the required energy. But merely the availability of materials and the required energy and other utilities cannot build the factory; it requires the know-how and effort of the men to plan and do the job. Along with the materials and energy, there must also be the contribution of 'Will force' having the Intelligence Potential necessary to bring about a state of order in these energies and materials to make up the factory. It is thus clear that if there were no such intelligence or will potential on the part of the human beings, the desired job could not be done just by leaving the mechanical or electrical energy and the materials to themselves. In other words, in the equation representing the second law, the apparent work function does not give the whole picture by itself. It must have associated with it not only the element of energy or work but also the will and the intelligence potential to get the work done.

We may extend our discussions further. In Nature, within the purview of human perception and knowledge, there are numerous potential energy sources which are either latent or which are scattered and apparently wasted or remain trapped at higher potential levels. By controlling the release of the latter tremendous amount of work can be performed. In fact, most of the energies for practical development of the civilisation upto the present day have come from these sources. But had there been no living beings, such sources would have remained untapped, awaiting some civilization. Had Nature been left to herself, all that could have happened is that such energies would have ultimately degraded to approach the definite final stage of some kind of equilibrium.

The obvious deduction therefore is that, for any utilisation of available energy in Nature, there must

be an intelligence potential with the will to harness all of them in an orderly manner so as to have the desired transformation. Since the beginning of the living beings till the present date, natural orderly changes could not have been effected without what may be called "Potentials of Will and Intelligence".

Now let us examine the work function of the second law in this light. For raising a quantity of heat from a lower to a higher temperature, the work expressed in conventional term, forms one part. Now this amount of work must be put to use by some intelligent agency with necessary 'Will'. The process will be most efficient when the magnitude of extra work input will be least. It has been established that this magnitude of work is least, if, in the process, the work can be carried out in a reversible manner. Left to itself this can never be achieved; Nature cannot but undergo transformation irreversibly. The part that the external agency should play in bringing about the most efficient transformation is to supply the will and intelligence potential to carry out the work as near to reversibility as possible. It follows, as a corollary, that the more refined technical means and better know-hows, the better will be the efficiency. In other words the higher and more perfect the intelligence and will potential, participating in effecting the change the more the process is likely to become reversible.

The above deductions lead to two important conclusions. Without Intelligence and Will Potential material energy cannot be harnessed for transformation which depends on the level of intelligence employed to effect the transformation. It is also clear that the influence of the external agency is always towards reducing the system and the process towards lower entropy than would have resulted if the transformation were left to itself. Obviously, whereas a primitive brain could perhaps carry out such a transformation with very great difficulty at very low efficiency, the law demands that only with the perfect Intelligence and Will the transformation can be conducted in a perfectly reversible manner.

**Dualistic Nature**

The Second Law of thermodynamics has been extensively applied in many ways in utilising the available potential sources of energy for the service of man. Its application has resulted in development of equipment and machinery in stages, one after another, giving more and more efficient performance. In the development and formulation of scientific laws, however, the impact of Nature as one possessing a life force or soul of its own as intelligence of consciousness potential has been ignored in as much as Nature has been conceived of as inanimate material object exclusive of soul. The influence of animate nature involved in scientific and technological laws has not also been considered to be essential and important, not to speak of its dominant influence. In other words, technically, Nature has never been considered to possess soul or life as a property; it has been only regarded as exclusively material. Tracing back their evolution and development, living beings, i.e., the animate nature, can certainly trace back their origin to the remote past as old as the material Nature itself; or at least to the time when the phenomena of the inanimate nature undergoing degradation, necessitated the advent of life on the planet to retard such degradation. The Second law of thermodynamics has brought out the fundamental fact that, had inanimate nature been on its own, it would invariably (in the context of the surroundings the living beings on earth can conceive from experience) tread an irreversible path towards a state of rest or equilibrium. Nature has not done so till now in this manner. And the same second law of thermodynamics also demands that to undo this inanimate natural degradation an external agency "must act upon" it to reverse the process. This has great significance with regard to the constitution of Nature itself. This aspect of "external agency" in Nature, which must possess intelligence, and will Potential or, so to say mind and consciousness, is nothing but the attributes of animate nature. There can be hardly any doubt about it.

Thus Nature comprises two distinct fundamental characteristics; one which is inanimate and has no control on its actions and the other which is animate whose actions are controlled and initiated by potentials of will and intelligence i.e. by mind and consciousness which influence the inanimate Nature.

Inanimate Nature follows the second law towards irreversibility and animate Nature nearer towards reversibility. These two characteristics of Nature arise out of necessity and are dictated by factors as directions either towards static or dynamic states. Whatever action is taken by the one the opposite reaction occurs in the other. In other words, the function of the animate Nature normally is opposite to the ways and functions of the inanimate Nature. The effect of the one obviously tends to annul the effect of the other. The above shows that animate nature is the active agent in Nature's functions to prevent the degradation of inanimate nature.

**Natural Degradation and Animate Nature**

Every action has its opposite reaction. Common experience applied to material Nature shows that, left to itself, its tendency is towards degradation in an irreversible manner towards maximum entropy. If the tendency of inanimate Nature is to act in this manner, then this very action also calls for the existence of something else whose activities would produce an opposite effect. In Nature, as per our perceptions, we do not see the existence of any other entity which can cause this effect, except the living beings. It can therefore be accepted that the advent of life has been necessitated by the degradation of material nature towards maximum entropy as an annuling force to combat it. Biological analysis of living beings suggests that living beings consist of matter, which is normally more orderly in itself which tends to develop towards minimum entropy. In this light, it has been suggested that they do so by feeding upon so-called "negative entropy". But the question as to the nature of this negative entropy remains open. It has been pointed out in the discussion earlier that it is not just the living beings which can effect the reversal of material natural changes, but it is their potentials of intelligence and will force that are the prime movers. It will be admitted that, when the living organism was first formed either in the form of Amoeba or Algae, it possessed very little will or intelligence.

An overall analysis of the evolution and development of living beings would show that they have grown stage by stage towards more and more intelligence. They also developed in physical characteristics from a dormant stage towards more and more mobile or variable aggregates during the process of evolution. It is however for the biologists to say how this simultaneous or parallel development of characteristic properties of animate beings, associated with more orderly constitutional development, are connected with the various stages of evolution. However, the history of evolution reveals some fundamental properties of living beings. Their constitutional evolution is associated with more order from one stage to the next. The overall effect of their actions is towards creation of more orderly situations; and the overall effects of their thoughts is towards more orderly concentration (i.e. potential) and intensity of thought. In other words, every aspect of living beings in their process of evolution and development is associated with increasing orderliness, and decreasing entropy. While discussing the second law of thermodynamics we have seen that more intelligence and more organised will lead towards bringing more and more order into Nature and that initiation of a change requires the existence of something *inexplicable* in living beings. In the creation of living beings, therefore, it was not merely the advent of some orderliness in matter; but also some intelligence give meaning to life. The living organism has undergone gradual development in its intelligence and will force along with its physical development. The mechanism of imparting life to orderly matter to create living beings however is not yet known. The evolution from static inanimate stage towards the dynamic stage of living beings remains a subject for scientific analysis, as also the correlation between higher potential development in intelligence and will, these questions will perhaps remain unanswered for quite a long time to come. Mere inability of our material and technological means to analyse this aspect of life should not stand in the way of the direct corollary that life and living being cannot be wholely defined by mere orderly matter being fed by 'negative entropy'. It demands the existence in association with it of something supernatural. The overall picture that emerges from the history of evolution of living beings is that from beginning they have progressed in every respect more and more towards minimum entropy. The second law of thermodynamics has shown that the growth towards higher state of intelligence and will etc., lead also to their ability to effect changes in nature towards more and more perfect order or in other words, towards minimum entropy. However, the question whether the creation of life coincided exactly with the time of start of degradation of Nature cannot be answered. But the nett result of creation and evolution of life cannot thereby lose significance.

In the course of discussions before, it emerged that whenever there has been any involvement of living beings in any transformation of inanimate material nature, invariably the effect is towards rendering the process closer to orderliness or reversibility. We have also seen that the higher the thermodynamic efficiency achieved in such a process, the higher would be the employment of efficient techniques. The latter obviously result from higher intelligence and will skill. The association of intelligence potential of living beings with orderliness and reversibility in every respect is thus a fundamental fact.

We can now discuss the most perfect order and the most perfect reversible process. Although the progress of human ingenuity in carrying out energy transformations or processes efficiently has been considerable, particularly when viewed in the light of primitive people only applying animate force to carry out such work vis-á-vis the means which are now adopted by modern

developments in technology to do the same, yet the question, whether a living being can carry out a process in a perfectly efficient and reversible manner by whatever efficient means at its disposal or it may discover in future with newer technological discoveries, has to be decided. This is indeed a moot point to settle—if human beings with their will and intelligence potential together would be able to devise means to carry out natural transformations in perfect reversible manner. Perfect reversibility is almost an impossibility to a living being. Reversible processes are necessarily infinitely slow processes. Therefore, although it may be humanly possible to imagine a machine which may work in perfect reversibility, in practice there must be some irreversibility attached. Any means adopted by using material means would have invariably associated with it in the process an amount of irreversibility.

**Summarising**

A living being constitutionally made of relatively orderly matter on the one hand and potential of intelligence and *will* on the other is the animate matter. Although the animate matter may be composed of relatively more orderly aggregates than found in inanimate nature, yet they cannot be perfectly orderly. The induced intelligence potential which is associated with the matter to some extent influences its direction towards orderliness; without this potential, no orderliness could be possible. This leads to the conclusion that living beings must have originated from interactions of some super intelligence and matter. Therefore, we can clearly see 3 states: the first—the state of super-intelligent order, the second—the stage of animate matter which is the intermediate state, and the third—the stage of purely inanimate matter. The first exists in absolute orderliness and treads the path of reversibility and leads others also towards the same end. The second is induced or degraded orderliness which can cause transformation, in a limited way, of material nature towards more orderliness; the third only reduces ultimately everything to disorderliness.

**Thermodynamics and Universe**

Clausius summarised the essence of thermodynamics as follows: "The energy of the world is constant but its entropy tends towards maximum". If we apply this today to the universe as a whole with our present knowledge there is no difficulty regarding the first portion viz. constancy of energy. But, when the entropy concept is applied to the universe as a whole, we meet with difficulties. For example, it demands that we accept that the universe as a whole is undergoing natural degradation: this brings in the difficult question about the beginning and end of the universe. It also means that the Universe does not maintain any overall equilibrium. To us, even from superficial consideration, the implications involved do not seem to be quite all right. This may therefore be analysed in the context of the perspective concept of the world and the universe. To clarify our views, we shall adopt a model in the following:

Let us assume a spherical balloon of perfectly elastic material which can assume any size, including expansion to infinity and contraction to zero. Let this contain a mixture of gases whose imaginary molecular weights may vary from very light to as heavy as possible. Let the average temperature of this gas be say 40°C. The balloon containing the gas as such, is isolated although it can expand or contract to any size as is demanded by its change in properties under various conditions. There is no external transfer or inter-change of matter or energy. In this picture, the various molecules will have varying energy conditions, velocities and molecular weights. Suppose at random in any portion within its overall space, we select 1 c.c. of space in which there are several numbers of molecules having varying weights. The distribution of energy, velocities etc. of the molecules at any instant within the unit volume may be known from the kinetic laws of gases. The molecular weights may vary between, say, 1 to 100. Suppose that, on one of the molecules having a mass of, say, 30, a very minute ultramicroscopic but intelligent virus is making observations. It will find that in the neighbourhood of the molecule, on whose surface it is living, there are a number of others whose temperatures, velocities are different and a few probably having higher energies and some decreasing in temperature at the same time. For the present, let us forget that all molecules are in the process of giving out or taking in space volume beyond the one c.c. concerned. In another 1 c.c. selected simultaneously at random from another location situated at a different region if we have another virus sitting on one of the molecules there it might find that all the neighbouring molecules are running down in energy. Obviously the virus in the second case will witness that the entropy of the system, it is conversant with, is increasing. While the virus in this case will experience that in his sphere of observation entropy is increasing, the other will observe that it is decreasing. If we extrapolate this picture, we can visualise our experience of the human being on the earth vis-á-vis the universe. Our case is similar to that of these viruses. It is not yet known to what extent the universe extends;

how many numbers of the nebulae there are and how many suns etc. Their temperatures and other conditions are also not precisely known. *Therefore the observation made or the experience gathered from perception of a section of the universe should not be extrapolated to define the total universe in its entirety.* Again referring to the case of the balloon, information on the overall energy condition and the average temperature could be found from the kinetic theory. So also the energies of the particles in each one c.c. volume. The properties of the molecules can vary widely from location to location. There can be local decrease or increase in entropy, but the balloon as a whole has been isolated and its contents are in overall equilibrium. The entropy of such a system should remain constant. Although at individual locations there may be increase in entropy, in other there is decrease in entropy. The resultant effect of all such local variations can tend to neutralise one another. This is the picture which should be applicable to the universe as a whole comprising everything that can be conceived of in the context of present knowledge and intelligence.

This must be the picture, as we shall see later also, when the total resultant effect of the various natural transformations throughout the universe are taken into consideration. There may be at one region in the universe local degradation of the material nature, which is being countered by the effect of animate nature. This process must be repeated in all parts of the universe where such conditions prevail.

In our view the universe maintains itself in overall equilibrium and it is not as a whole drifting either towards lower or higher entropy. Though the average conditions of the universe as a whole is difficult to imagine, it should not be unreasonable to presume one such exists, whatever may be its quantitative value.

If the conservation of energy is applied to the universe as a whole, the unilateral concept of trend towards maximum entropy would not be applicable to such a system. However, when the principle is applied only to the section of the universe with which we are acquainted, say, Earth, Moon, Stars, Mars, Venus, etc., and attention is confined to their cross-section of the universe under the present set-up of conditions (not in the universal context of overall equilibrium), it is probable that the tendency towards maximum entropy might be apparently justified. However, in such an assumption, we have to ignore the effect of radiations and other influences from the rest of the universe towards this portion, and also the effect of animate nature. So far as the material nature is concerned, there may be the appearance of entropy in this portion of the universe drifting towards maximum. In the trend towards maximum entropy in a particular portion, we are only talking about the trend in the inanimate nature. We have not considered what the overall position of this apparent trend would be when considered along with the concept of animate nature. Obviously, if we take the simultaneous effect of animate nature into consideration, besides the concept of trend towards maximum entropy in this portion of the universe, it would also be found that this trend is being simultaneously contradicted by the opposite trend towards minimum entropy by the animate nature.

The presence of living beings in other planets hinted at from time to time should, therefore, not cause any surprise. If the advent of animate nature is a must to help prevent degradation, it will evolve so as to survive under any climatic and other conditions.

The phenomena of the advent of animate nature has not yet been explained; it is still a mystery. As has been discussed earlier, its advent is associated with the infusion of some intelligence potential into the matter in somewhat orderly form to start with. Nature as such, as has been discussed before, left to itself, would only lead to disorderliness and degradation of energy potential. This also means that animate nature, which requires orderly matter to sustain and thrive on, could never have evolved from inanimate nature by itself. Some direct assistance from a supernatural agency is therefore inevitable. It is known that a degree of orderliness in a disordered mass, can be introduced by induction by a orderly higher potential, just as a magnet can induce order and electromagnetic potential in disorderly iron fillings. It is therefore reasonable that the advent of life in this disorderly nature has been produced by induction from a supernatural external agency, in infinitesimal amounts, because it has been seen before that the agency acts in reversible manner. The induced potential of intelligence is reflected in the animate nature in its orderliness. The presence of animate nature in the universe has thus to be treated as part and parcel of the universe itself. If the contention that the universe is maintaining overall equilibrium will receive acceptance, it follows that in those regions, where there is degradation, there is animate nature to work for maintenance of the overall balance.

**External supernatural agency**

In all the above discussions we have come to the one and only conclusion that in whichever way the constitutions and the existence of the universe as a whole and

the various phonomena and manifestations in different regions are analysed, an overall equilibrium cannot be achieved without the help of an external agency which induces potential in this inanimate universe and produces animate nature. Naurally, therefore, enquiries should be made regarding the description and characteristics of this external agency. Thermodynamical analysis has shown that the external agency, while carrying out a transformation most efficiently, does so in a perfectly reversible manner, perfect knowledge, intelligence and consciousness are implied therein. A reversible process is an infinitely slow process. The supernatural agency, therefore, must exist in some perfectly static equilibrium. The supernatural agency introduces by induction orderliness and intelligence potential when animate nature is formed. The infinitely high potential and orderliness of the external agency is thus ensured. The animate nature must be prevailing throughout the universe in various forms in various regions. The external agency has to be simultaneously present in inducing and controlling animate nature. This dictates its property of omnipresence. Thus orderliness, omniscience, omnipresence, omnipotence in perfect orderly equilibrium of infinite calmness are the characteristics of that supernatural agency one has to reckon with. These would be the characteristic properties of the Absolute.

The above characteristics of the external agency also lead us to the following conclusions. No action can take place in the universe without the aid of or without being caused by an external agency. For its efficient action, this agency must necessarily be in a static state of existence, possessing certain potential force to cause the action to take place in a reversible manner and the magnitude of its potential or intensity would be of infinite order. These would also be some of the properties of the fundamental dimension which can cause the manifestation of the universe as it is. The fundamental dimension, after causing the creation, must simultaneously generate opposing dimensions for establishing overall equilibrium in the Creation.